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Page 188: - *Lenzites saepiaria* (Wulf. ex Fr.) Fr.

Delete: See *Gloeophyllum hirsutum* Schaef. ex Murr.

Insert: See *Gloeophyllum sepiarium* (Wulf. ex Fr.) Karst.

Page 210: - **Neobulgaria pura* (Fr.) Petrak.

Delete: (*). Previously published in Fungi Canadenses No. 85. 1976.

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La Revue *Proceedings of the Nova Scotian Institute of Science* publie les travaux de l'Institut, des articles originaux et des notes avant trait aux sciences naturelles aux Provinces atlantiques, surtout dans les domaines de la biologie et de la géologie. Les manuscrits peuvent être en anglais ou en français, et seront soumis à l'avis d'experts avant d'être acceptés.

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Volume 33, pp. 1-6

DISCOVERY OF AN UNDISTURBED BED OF 3800 YEAR OLD OYSTERS (CRASSOSTREA VIRGINICA) IN MINAS BASIN, NOVA SCOTIA

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and

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Near Evangeline Beach, Minas Basin, a recent secondary outflow channel of the Gaspereau River has removed the overburden of soft sediments across 3 km of intertidal flats. About 2.2 to 2.3 km from shore it has exposed a 4400 year old forest, and a saltmarsh and oyster bed dated near 3800 yrs B.P. Many of the valves of both the marsh ribbed mussels *Geukensia demissa* and the subtidal oysters *Crassostrea virginica* are erect and paired indicating rapid burial *in situ*. Interpretation of mussel and oyster valves and associated plant, ostracod, foraminiferan, gastropod and pelecypod material entombed in the same deposit indicates that the marine environment at that time was optimal for oysters, that water temperatures exceeded 20°C in summer, that salinity was 20-25°/oo, that there was a sheltered low energy shore, and that both tidal amplitude and turbidity were increasing.

Près de la plage Evangéline, bassin Minas, un recent chenal secondaire d'ecoulement de la rivière Gaspereau a enlevé sur 3 km les sédiments mous qui surchargaient les plaines intertidales. A environ 2.2 à 2.3 km du rivage, une forêt vielle, de 4400 ans a été exposée ainsi qu'un marais salant et un banc d'huîtres datant de près de 3800 ans. Plusieurs des valves des moules striées de marais *Geukensia demissa* et des huîtres infra littorales *Crassostrea virginica* sont érigeés et placeés par paire, Ce qui indique un ensevelissement rapide *in situ*. L'intérprétation des valves de moules et d'huîtres ainsi que les restes de plantes, d'ostracodes, de foramiuifères, de gastropodes et de pélécypodes ensevelis dans le même dépot indiquent que l'environement marin de cette époque était optimal pour les huîtres, que la température de l'eau en été dépassait 20° C, que la Salinité était de 20°/oo à 25°/oo, qu'il y avait un rivage abrité et que l'amplitude des maries ainsi que la turbidité augmentaient.

The complex of submerged forest of pine and hemlock along the southwest shores of the Minas Basin (Fig 1) have been the subject of several studies (Goldthwait 1921; Lyon & Goldthwait 1934; Harrison & Lyon 1963; Grant 1975). These surveys were limited to the "Guzzle" area, a deep channel between Long Island and Boot Island, with the exception of Lyon and Goldthwait (1934) who followed the outflow channel northwards across the intertidal flats for a distance of "half a mile". In 1977, Acadia University students discovered an area of exposed forest, salt marsh, and an oyster bed 2.28 km NNW of Boot Island (Fig 1). The forested area has been carbon dated to over 4400 yrs B.P. and the oyster bed is dated near 3800 yrs B.P.

Results of radiocarbon dating of three individual oysters (*Crassostrea virginica* (Gmelin) were 3750±60 and 3720±60 yrs B.P. (GSC-2598, GSC-3043), and 3615±100 yrs B.P. (DAL-296). Two lots of ribbed mussels (*Geukensia demissa* (Dillwyn) provided C^{14} dates of 3800 80 (GSC-3040) and 3310 125 (DAL-362).

Of particular significance is the undisturbed condition of the entombed fauna. The explanation of why this area is only now being exposed has not been given

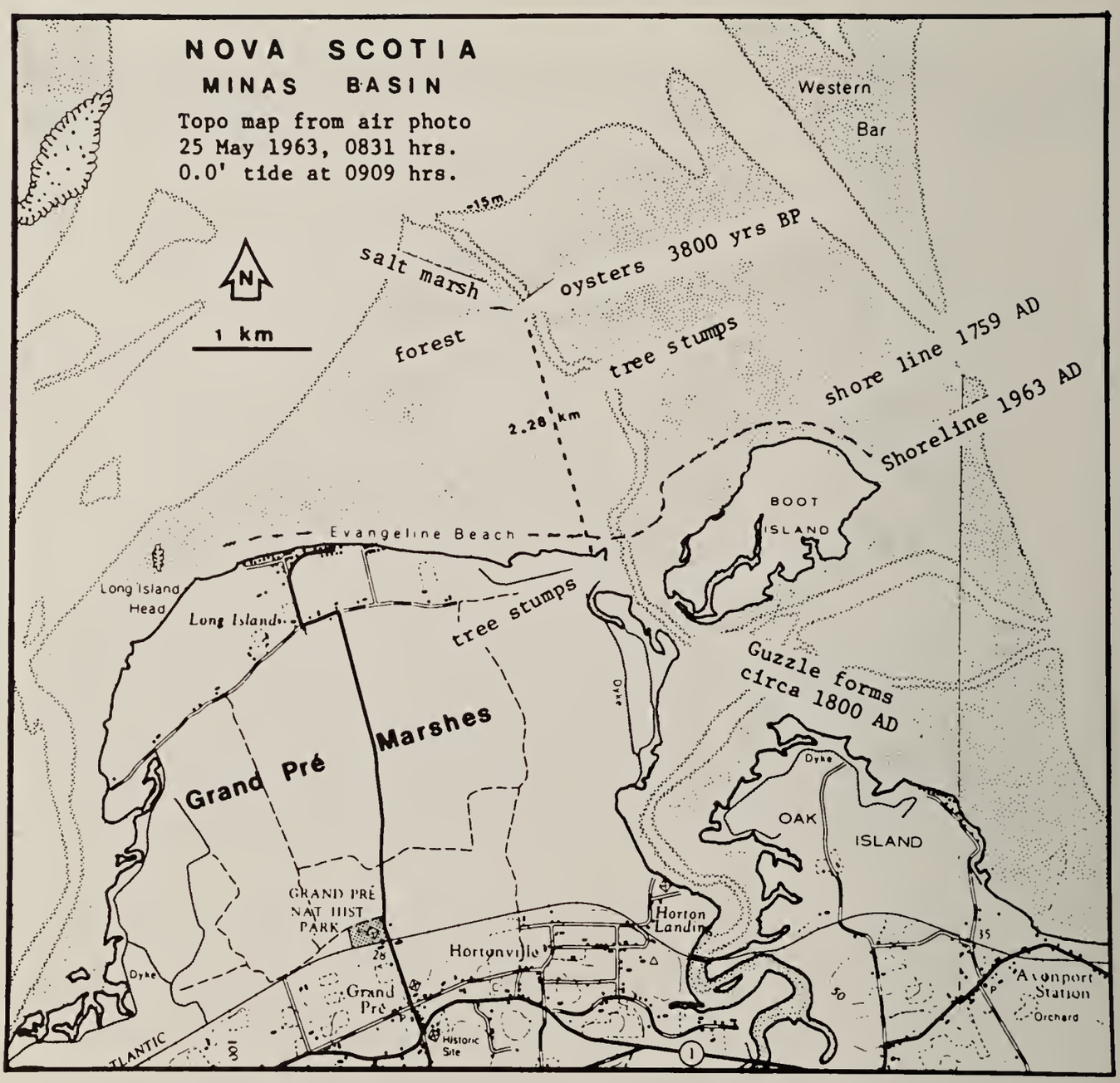

Fig 1. Location of oyster bed and general topographic features mentioned in the text. Note changes in the Guzzle area by comparing with Fig 2 and 3.

due emphasis in the literature. The present Guzzle channel is an early post-glacial valley that became forested and subsequently (over the past 4500 years) submerged and buried beneath marsh and marine sediments. The original forest that blanketed the ridge and valley contours of that period was eventually capped by an immense flat salt marsh, the Grand Pré of Acadian lore. That marsh joined Long Island and Boot Island and the mainland, as the British Land Survey of 1759 so nicely depicts (Fig 2). The map series of 1759, 1911 and 1963 (Figs 2, 3, 1) trace the history of coastal erosion on the north exposure of the marsh, an erosion that eventually opened into a major marsh channel that in turn drained southward into the Gaspereau River. Beneath this marsh channel was the old forested gully. By the 1940's, it had been excavated nearly to its original level revealing on its slope an historic series of tree stumps. The channel scouring is, therefore, very recent and is continuing to erode away the protective cover of deposits across 2.5 km of intertidal flats, apparently following the original post-glacial gully.

The oyster shells are protruding from a gray clay deposit, 1.6 ha of which is exposed. This bed is table-top flat, about 1.5 m above Chart Datum and only 0.3 m

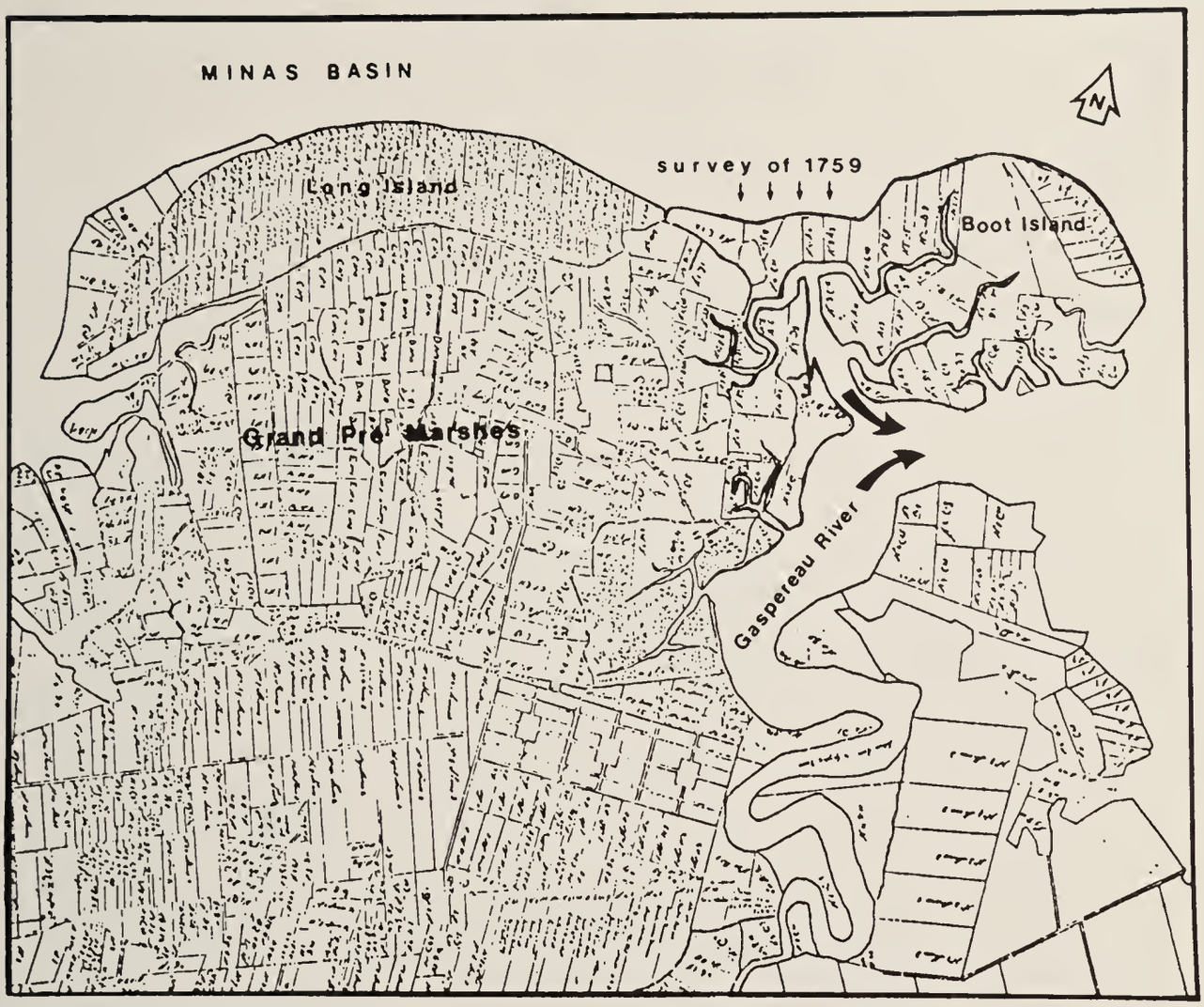

Fig 2. British land survey map of 1759. Note that the configuration of the marsh drainage creeks on Boot Island was still the same in 1963 (Fig 1) but that coastal erosion on the north side of Boot Island had nearly obliterated one of the two major creeks.

below the forested area 120 m to the south in the small gully. By the time the subtidal oyster bed had developed, 3800-3700 yrs B.P., the trees had died, fallen over and been buried by sediments several hundred years previously (C^{14} dates of trees from that elevation: 4470 ±60 (GSC-3105; 4455 ±130 Isotopes Inc.; 4115 ±235 and 3675 ±235 DAL-361). At the time the oysters died, turbidity, sedimentation and rising sea levels must have been accelerating, for, although the growth pattern, shellshape and surface sculpturing indicate a subtidal environment, most of the oysters are attached to ribbed mussels which are usually indicative of salt marshes. Today ribbed mussels are extremely rare in Minas Basin marshes and oyster colonies have not previously been reported nor have their valves been found in shell middens at local archaeological sites. Whatever the circumstances, the process of sedimentation at 3800 yrs B.P. buried the marsh and the oyster communities so quickly and gently that delicate shells, fragile surface sculpturing and even the proteinaceous periostracum remained intact. The fact that so many of the ribbed mussels and oysters occur as paired upright valves also indicates death *in situ*. The wedge-shaped, elongate, upright valves of many of the oysters indicates they were struggling to keep ahead of the rapidly accumulating sediments. Additional indirect evidence of high turbidity and sediment loads is the absence of a successful spat fall over this bed. Only one valve of about 160 examined had other oysters attached: a 7 cm and a 13 cm valve on a 17 cm individual.

As the growth rings on the oysters are wide and evenly spaced and valves of 25 cm in length were but 16 to 18 yrs of age, conditions must have been optimal.

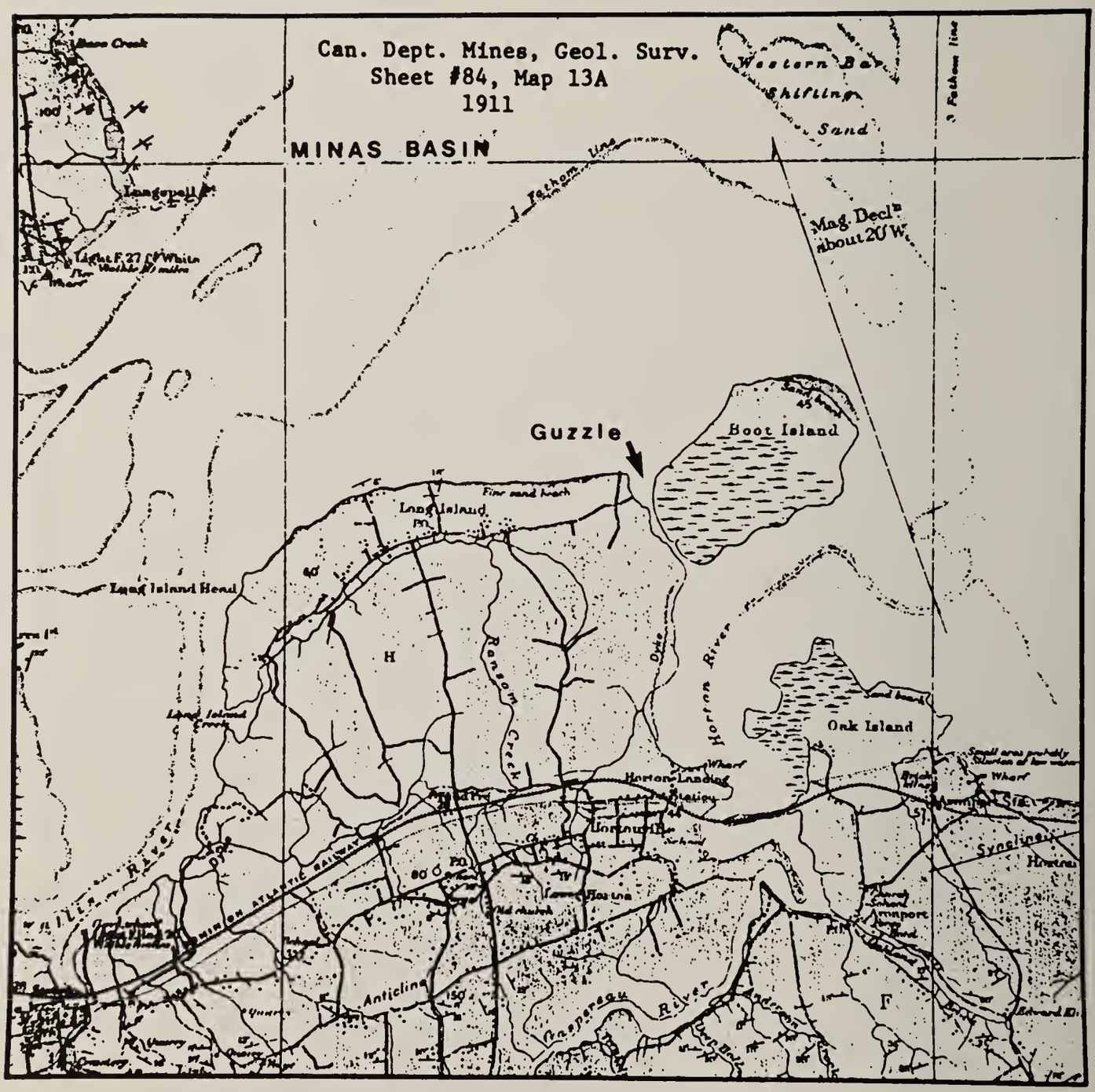

Fig 3. Note the narrow Guzzle of 1911 and absence of any representation of a channel across the broad intertidal flats. The 1928 topographic edition depicts a much wider Guzzle but also lacks the very evident north-south channel of the 1967 map issue (Fig 1).

Summer seawater temperatures would have exceeded 20°C, a requisite for oyster reproduction. The paucity of worm burrows of *Polydora websteri* Hartmann in these thick valves and absence of burrows of the sponge *Cliona celata* Grant indicate salinities of 25°/oo or less and silty conditions (Roy Drinnan, in verb.). These conclusions are substantiated by the foraminiferan assemblage extracted from the clay found on and between valves of the oysters. The six species in order of abundance are: *Elphidium excavatum* (Terquem), *Protelphidium orbiculare* (Brady), *Pateoris hauerinoides* (Rhumbler), *Trochammina inflata* (Montagu), *Ammonia beccarii* (Linne), and *Trochammina macrescens* Brady, a group found in water that is reasonably quiet, warm in summer, and inshore in type. Similar faunas are to be found today in the southern half of the Gulf of St. Lawrence, Northumberland Strait, St. George's Bay and the southern half of Baie des Chaleurs (Fiona E. Cole, in verb.).

Gentle washing and seiving of clay adjacent to and adhering to the oyster valves produce a wealth of well preserved seeds of *Ruppia maritima* L., an aquatic plant of salt marsh pools; stems and leaves of *Spartina* marsh grasses; polychaete jaws; ostracods; foraminiferans; gastropods; and pelecypods. The general assemblage of the ostracod *Cytheormorpha curta* (Edwards) Darby, the gastropods *Littorina rudis* (Maton), *Hydrobia totteni* Morrison, *Ilyanassa obsoleta* (Say), *Odostomia trifida* (Totten), and the pelecypod *Gemma gemma* (Totten) are again indicative of a rather sheltered slightly brackish habitat bordering salt marshes.

Processing of clay trapped between oyster valves yielded two additional gastropod species: the low water *Nassarius trivitattus* (Say) and *Pyramidella (Sayella) fusca* (C.B. Adams). The latter, and *Odostoma trifida,* are typical today of sheltered muddy inlets that harbour oyster beds.

A similar treatment of clay from between paired valves of several ribbed mussels again revealed *Littorina rudis, Hydrobia totteni, Gemma gemma* and four significant specimens of the pulmonate marsh snail *Melampus bidentatus.* The latter is common in coastal marshes along the Atlantic shores of Nova Scotia (Bousfield, 1960) but has not previously been reported in the literature from Minas Basin. Thus *Pyramidella, Crassostrea,* and *Melampus* are recorded from Minas Basin only as sub-fossils.

With rising mean sea levels accompanied by a relatively rapid evolution of megatidal cycles about 4000 to 3500 years B.P., environmental conditions changed in the Minas Basin (Amos, 1978; Amos & Bleakney in preparation). Oysters became extinct probably prior to 2500 yrs B.P. because shell middens in the Minas Basin area contain quantities of soft shell clams (*Mya arenaria* L.) but not oysters, even though the earliest shell cultures were oyster gatherers followed much later by the digging of bivalves (Erskine, n.d.). Indian middens on the Atlantic and Northumberland shores of Nova Scotia are noted for oyster deposits (Smith & Wintemberg 1929; Erskine 1957-58, 1961, n.d.). According to Erskine the Laurentian Culture of hunters and fish eaters avoided shell-fish and first arrived in Nova Scotia about 3000 yrs B.P. Between 2400 and 1900 yrs B.P. several new cultures invaded the Bay of Fundy area and these were the first to introduce utilization of shellfish. It would appear that by then, oysters had been eliminated from Minas Basin waters. Also eliminated from the Basin, but not the rest of Nova Scotia nor the southern Gulf of St. Lawrence were *Pyramidella fusca* and *Melampus bidentatus* and reduced to the status of rare species within the Basin were *Odostomia trifida, Geukensia demissa* and the sponge *Cliona celata* (Bousfield & Leim, 1960; field experience of authors).

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The authors wish to thank Dr. Q.A. Siddiqui of St. Mary's University, Halifax, for examining the ostracod material, Ms. Fiona E. Cole of the Atlantic Geoscience Centre, Bedford Institute, Dartmouth, for identification and interpretation of the foraminiferal material, and Mr. Roy Drinnan, Fisheries and Oceans, Resource Branch, Halifax, for his examination of, and comments on, the oyster valves. Funding for this project through NSERC Operating Grant 2009 is gratefully acknowledged by the senior author.

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PREDICTING TROPHIC RESPONSE TO PHOSPHORUS ADDITION IN A CAPE BRETON ISLAND LAKE

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Freshwater Lake in Cape Breton Island is characterized by clear water (2-8 Hazen u), and high water temperature (10-12°C) and low oxygen levels (0-20% air saturation) in the hypolimnion in late summer. The lake receives ca. 27 mgP/m^2/y from developments and sea spray in addition to the natural, edaphic phosphorus load of 106 mgP/m^2/y. The lake is considered oligo-mesotrophic based on transparency (Secchi depth 7 m), total phosphorus (7.6 mg/m^3), annual mean and peak chlorophyll (2.5 and 6.4 mg/m^3, respectively), low hypolimnetic oxygen levels and relatively dense growth of macrophytes in shallow areas. A proposed development would increase the phosphorus load by ca. 5 mgP/m^2 during the summer which would increase the epilimnetic total phosphorus concentration to 8.6 mg/m^3 and peak chlorophyll to 9.8 mg/m^3, assuming an average lake response. These changes would place the lake into the mesotrophic category. Close to the outflow of the secondary treatment discharge, nuisance levels of algal response and macrophyte growth could be expected.

Vers la fin de l'été, le lac Freshwater, situé dans l'île du Cap Breton, est caractérisé par une eau claire (2-8 Hazen u), une température de l'eau élevée (10-12°C) et de faibles niveaux d'oxygène (0-20% de saturation d'air) dans l'hypolimnion. Le lac reçoit environ 27 mg P/m^2/ an des diverses exploitations et de l'embrun marin en plus de la charge naturelle de phosphore édaphique de 106 mg P/m^2/an. Ce lac est considéré oligo-mésotrophe basé sur la transparence (profondeur du disque de Secchi 7 m), le phosphore total (7.6 mg/m^3), la moyenne annuelle et le maximum de chlorophylle (2.5 et 6.4 mg/m^3 respectivement), le faible taux d'oxygène de l'hypolimnion et la croissance relativement dense des macrophytes en eaux peu profondes. Une proposition d'exploitation augmenterait la charge de phosphore de 5 mg P/m^2 pendant l'été, ce qui aurait pour effet d'augmenter la concentration totale de phosphore de l'épilimnion à 8.6 mg/m^3 et le maximum de chlorophylle à 9.8 mg/m^3, en supposant une reponse moyenne pour le lac. Ces transformations placeraient le lac dans la catégorie des lacs mésotrophes. Une croissance nuisible d'algues et de macrophytes peut survenir près de la bouche d'écoulement du traitement secondaire des eaux.

Introduction

Freshwater Lake (46° 38' 40''N, 60° 23' 45'' W) is the second largest lake in Cape Breton Highlands National Park and the largest boulder-beach (barachois) pond in the National Parks in Canada. Its location near the Park entrance, makes it highly visible and it is used for swimming. This necessitates that the lake and its catchment be managed to ensure its unimpaired recreational and aesthetic values.

Recently a development site on the northwest shore of the lake near the park entrance has been proposed as a preferred location for several reasons. Concerns have been raised about possible detrimental impact of the facility on the lake, which is already showing some signs of man-made eutrophication, unlike the other pristine, oligotrophic lakes nearby.

The freshwaters of Cape Breton Highlands National Park were surveyed during 1976 and 1977 and the information thus obtained was used in combination with some of the findings (Vollenweider & Kerekes 1980) of the Organization for Economic Co-operation and Development (OECD) Cooperative Programme on Monitoring of Inland Waters (Eutrophication Control) to evaluate the possible im-

pact of phosphorus addition on Freshwater Lake which might result from the proposed facility.

Methods

Sampling procedures and methods of measurements are given in detail by Kerekes et al. (1978).

Water temperature, dissolved oxygen, hydrogen ion concentration and specific conductance (low-range probe) were measured in situ using a Hydrolab Surveyor II instrument equipped with a 20 m cable. Chlorophyll-*a* and phaeophytin were determined by the fluorometric method of Yentch and Menzel (1963) as modified by Holm-Hansen et al. (1965). Total phosphorus was determined on unfiltered duplicate samples, digested with potassium persulfate (Menzel & Corwin, 1965). The phosphate thus produced was then estimated, along with inorganic phosphate originally present in the sample, by the method of Murphy and Riley (1962).

Annual total phosphorus loading and annual mean total phosphorus inflow concentration were estimated from lake concentration using the formula and its derivations developed by Vollenweider (1976).

$$(L(P)/q_a)/(1 + \sqrt{T(w)}) = [\overline{P}]_i/(1 + T(w))$$

$$[\overline{P}]_i \approx [\overline{P}]_\lambda \cdot (1 + \sqrt{T(w)});$$

$$L(P) = [\overline{P}]_i \cdot q_a$$

where $L(P)$ = specific loading of total phosphorus per unit lake surface area (mg $P/m^2/y$)

$[\overline{P}]_i$ = average annual inflow concentration of total phosphorus (mg P/m^3)

$[\overline{P}]_\lambda$ = average annual concentration of total phosphorus in the lake (mg P/m^3)

$T(w)$ = water residence time (y)

q_a = hydraulic load (m/y).

The validity of the estimated annual mean inflow concentration of total phosphorus (13.7 mg P/m^3) was checked by examining the available total phophorus concentration measurements taken once a month between April, 1976 and March, 1977 in one of the major inflow streams. The annual mean total phosphorus concentration of the inflow was found to be 9.5 mg P/m^3 ((range 4.8 to 15.0 mg P/m^3) monthly values). Occasional measurements taken in a minor inflow stream gave similar results.

Mean chlorophyll-*a* and peak chlorophyll-*a* concentrations were predicted from lake total phosphorus concentrations using the formulae developed by Vollenweider and Kerekes (1981):

$$[\overline{Chl}] = 0.28\,[P]_\lambda^{0.96}$$

$$[Chl]_{max} = 0.64\,[P]_\lambda^{1.05}$$

where $[\overline{Chl}]$ = average annual concentration of chlorophyll-*a* in the euphotic zone (mg/m^3)

$[Chl]_{max}$ = annual peak concentration of chlorophyll-*a* in the euphotic zone.

Description of Freshwater Lake

Freshwater Lake (Fig 1, Table I) is a barachois pond separated from the sea by a pebble barrier which forms Ingonish Beach. A public beach is located at the northeast corner of the lake. The National Park Headquarters and staff residences are on the northwest side. Residential and commercial developments (part of the village

of Ingonish Beach) and various roads on the drainage basin, all lie close to the lake. Beyond this area of development around the lake, the drainage basin is covered by white spruce, maple and balsam fir forest, underneath which lies compacted glacial till. Approximately 60% of the lake volume lies below MSL.

There is some evidence from specific conductance measurements that a small influx of saline water occurs during the winter (Fig 2), but in the spring and fall it mixes with the overlying water.

After spring breakup and a brief isothermal period, a layer of cold, dense, oxygen-poor water remained below 15 m depth, while water in the lake above it circulated freely (Fig 3). The epilimnion reached temperatures over 22°C while the hypolimnion was between 10-12°C. The volume of the hypolimnion decreased from 13% of the total lake volume in June (depth >10m) to 5% in September (>13m). During autumn mixing, the water gradually cooled off to around 1°C before freezing and warmed somewhat under ice by late March. Because long, windy, cool springs and autumns lead to long mixing periods, such relatively high hypolimnetic and cold under-ice temperatures are common in lakes in Atlantic Canada.

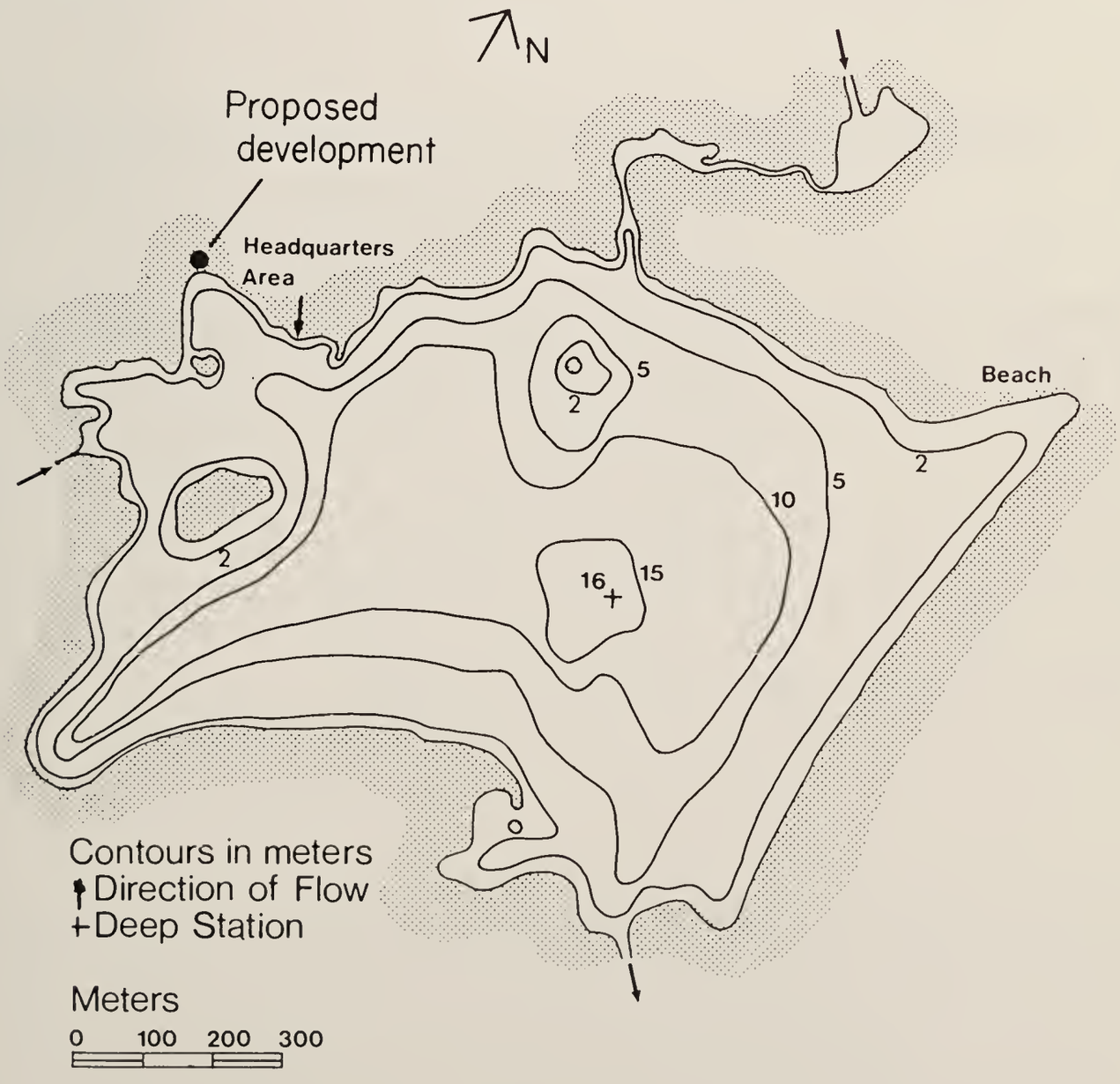

Fig 1. Bathymetric map of Freshwater Lake, Cape Breton Highlands National Park, Nova Scotia.

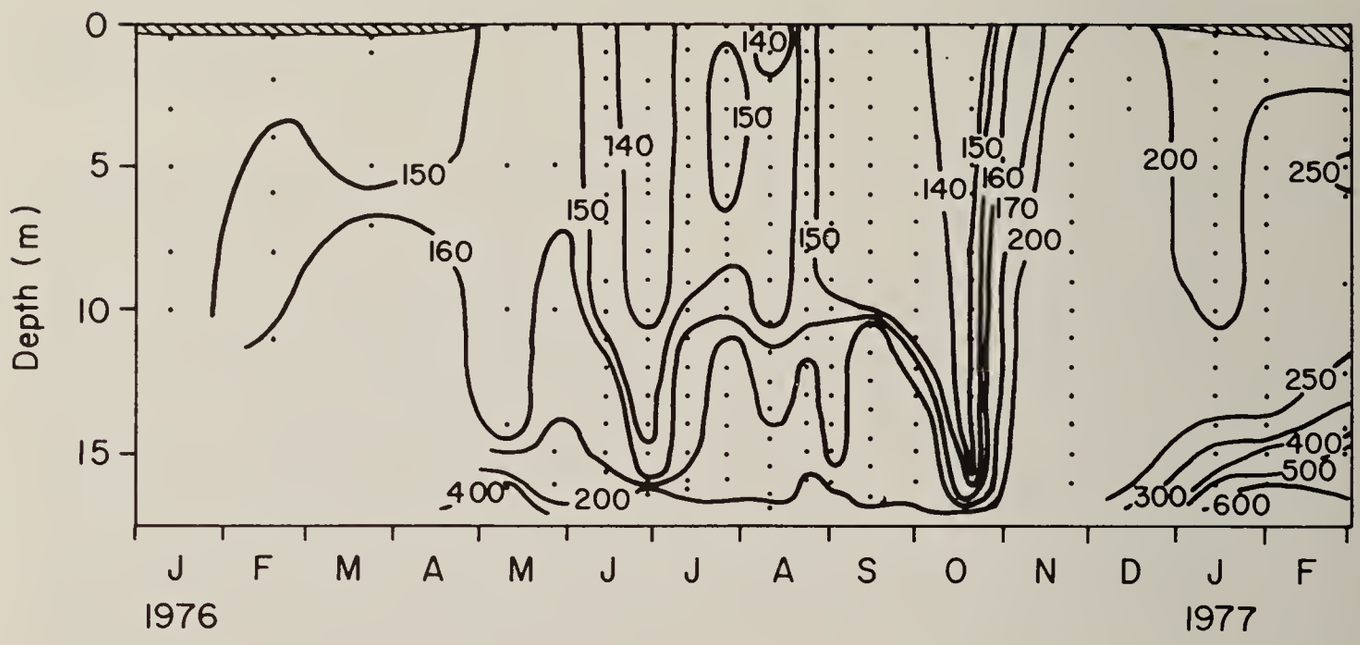

Fig 2. Isopleths of specific conductance μhmos/cm in Freshwater Lake. Dots in panel indicate depths of measurements on which the graph is based. Ice cover shown to scale.

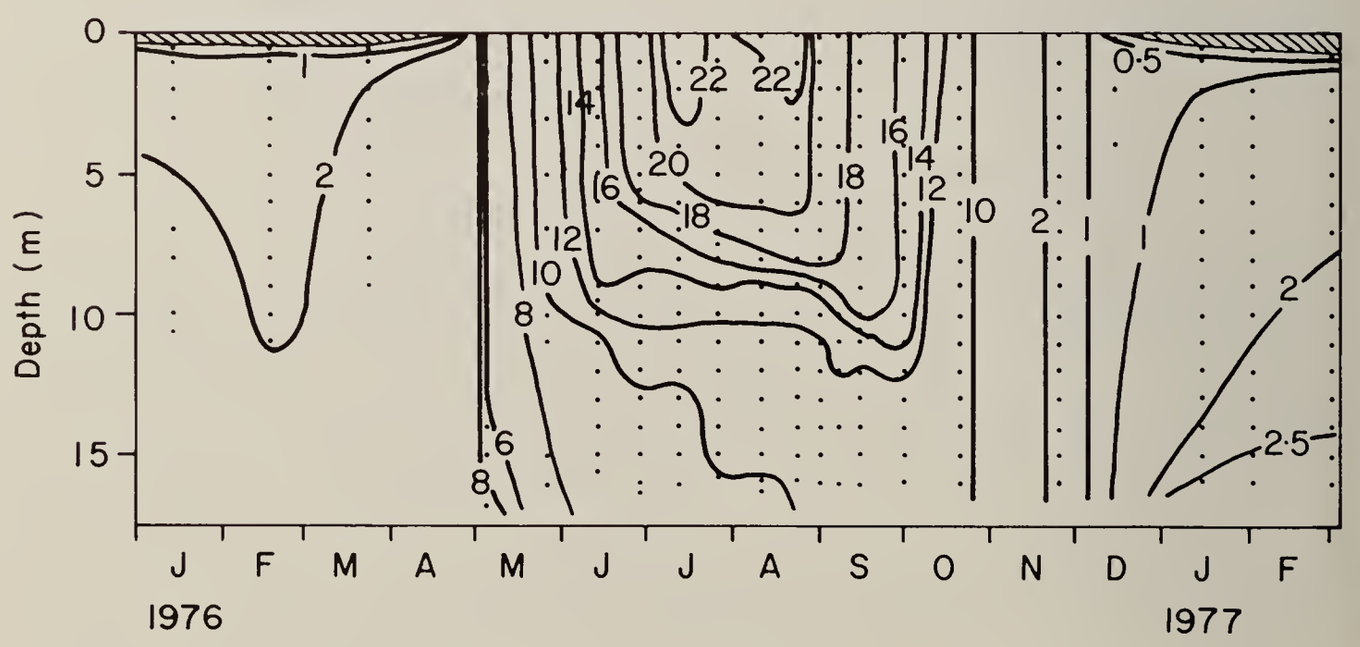

Fig 3. Isotherms °C of Freshwater Lake. See Fig. 2.

Dissolved oxygen concentrations in the euphotic zone were high throughout the study period, often exceeding air saturation (Fig 4). Hypolimnetic oxygen levels declined steadily throughout the summer and almost disappeared by mid-September. They remained above 50% air saturation during winter in all but the bottom meter of water.

The clarity of water in terms of both colour and turbidity, allowed the euphotic zone to extend to a maximum of 12 m depth with an ice-free seasonal mean of slightly over 11 m (Kerekes et al. 1981). Thus the tropholytic zone was restricted to the lower hypolimnion.

Table I. Selected morphometric and chemical features of Freshwater Lake, Cape Breton Highlands National Park, Nova Scotia.

Lake Surface, A_o 0.422 km²; Drainage Area, A_d 3.4 km²

Mean Depth, 6.49m; Max Depth, 16.3m; Cryptodepression Depth, 13.3m

**Water Residence Time, T(w) 0.67y; Water Surplus (runoff), ws 1.2m

Hydraulic load, q_a 9.69 m/y

*pH (range) 7.1 - 7.6; *Colour, 2 - 8 Hazen u

*Specific Conductance, 138 - 200 μmhos/cm, $\bar{x}$ = 164 μmhos/cm

*Secchi depth, 4.6 - 9.3m, $\bar{x}$ = 6.98m

Cations (mg/l)	Anions (mg/l)	(August 10, 1976)
Ca^{++} 11.0	HCO_3^- 15.1	SiO_2 0.2 mg/l
Mg^{++} 1.8	$SO_4^=$ 18.1	
Na^+ 19.5	Cl^- 28.0	
K^+ 0.7		

*Surface, ice-free period in 1976.
**$T(w) = z/q_a$
***$q^a = z/T(w)$ or $1_y/A_o$ where $Q_y = A_d$. ws

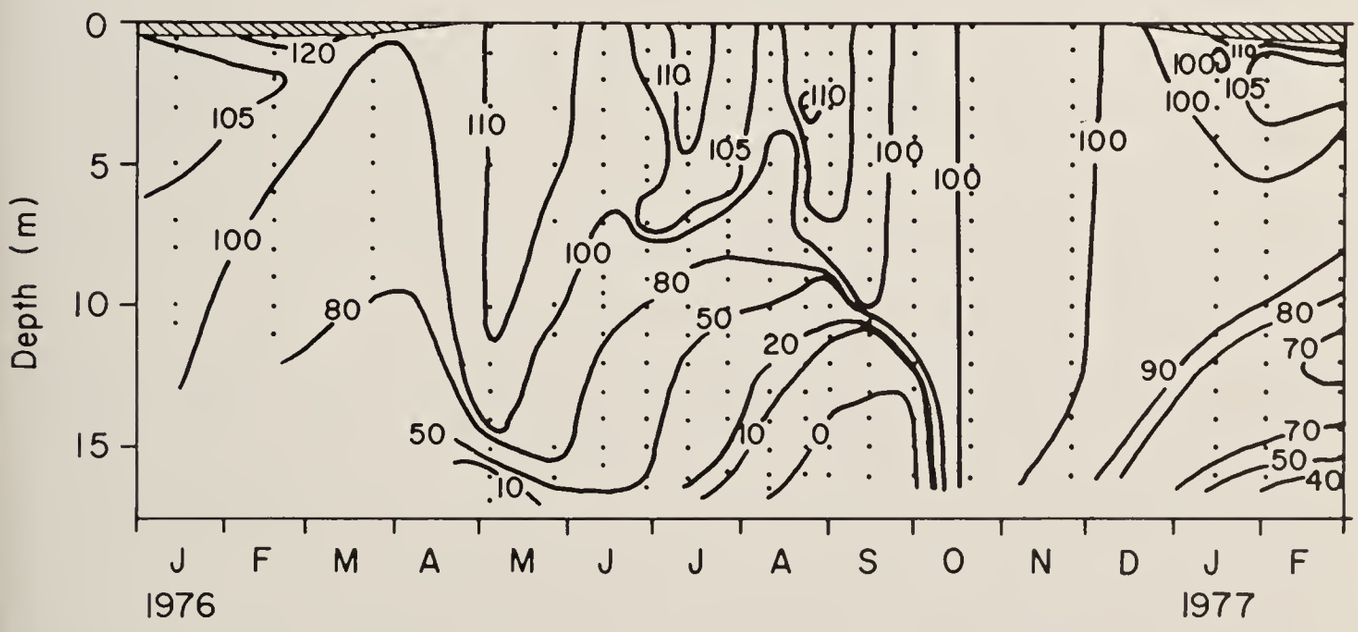

Fig 4. Isopleths of dissolved oxygen as air saturation in Freshwater Lake, January, 1976 - March, 1977. See Fig. 2.

The influx of some sea water either as salt spray or directly through the outlet stream during storms affects the water chemistry of the lake. Na^+ and Cl^- are the dominant ions and the specific conductance (Table I) is much higher than in the other lakes in the Park, with the exception of two ponds also located close to the sea. Winter salting of the highway in the lake's catchment also contributes to the

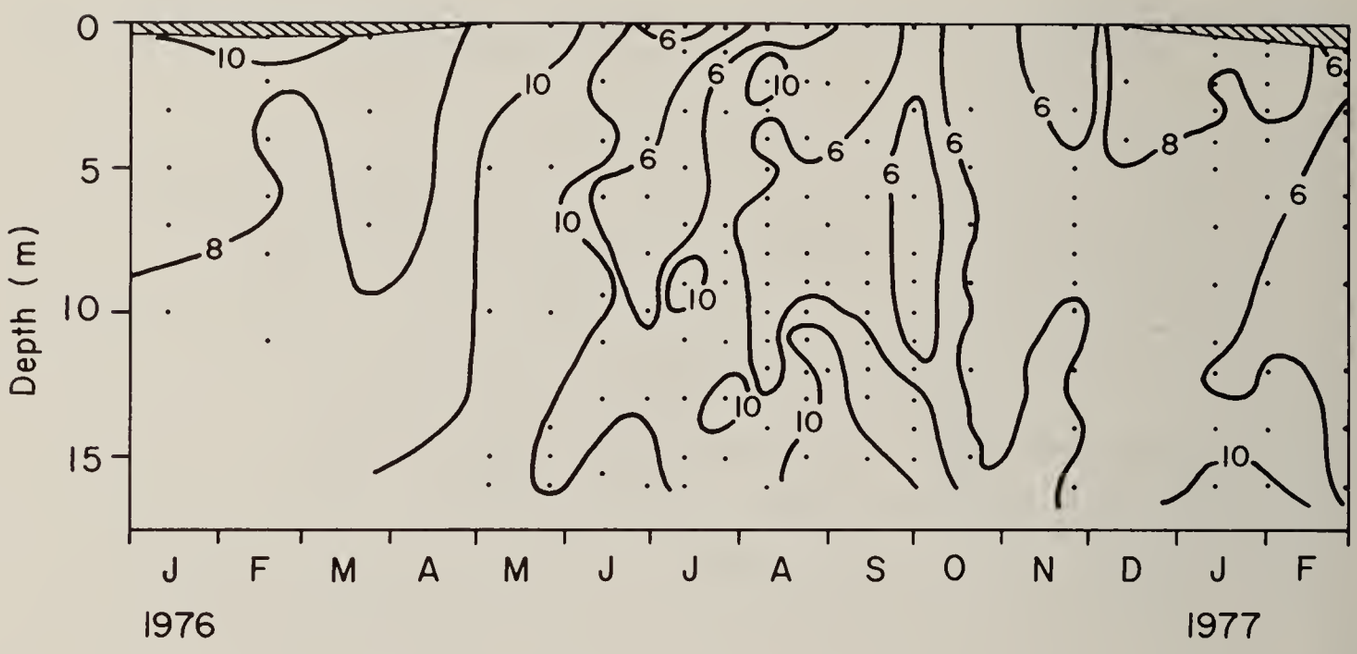

Fig 5. Isopleths of total phosphorus concentration (mg P/m^3) in Freshwater Lake. See Fig. 2.

high conductance. Specific conductance of 470 μmhos/cm was measured in one of the inflows in early March, 1976. Specific conductance through the water column increased considerably during the fall and remained high through the winter of 1976, higher than in the previous year (Fig 2). The winter influx of some sea water into the deepest part of the lake gave a specific conductance near the bottom of 680 μmhos/cm by March, 1976.

Total phosphorus concentrations were the highest after breakup in May (Fig 5). The mean annual total phosphorus concentration in the lake (7.6 mg P/m^3) is higher than in other Park lakes which were deep enough to stratify, including two pristine lakes (6.0 mg P/m^3) located approximately 5 km from Freshwater Lake. The somewhat elevated phosphorus concentration is presumably the result of human activity on the drainage basin and of the seawater influx into the lake. Total phosphorus concentrations remained low, about 10 mg P/m^3, in the deeper part of the lake at the end of the summer and during winter stagnation periods.

Mean total phosphorus concentrations in the mixed layer exhibited seasonal trends strikingly similar to that of chlorophyll-a concentration and turbidity (Fig 6). A spring peak of chlorophyll-a appeared in May, throughout the water column (Fig 7). During periods of thermal stratification the highest chlorophyll-a concentrations were found near 1% surface light intensity, i.e., at depths 10 m or greater, or 4 to 5 m under the ice. This condition has been described by Kerekes (1974, 1976) in Atlantic Canada and by Fee (1976) in northwestern Ontario.

Freshwater Lake exhibits annual mean and peak chlorophyll-a levels in relation to total phosphorus concentration that are higher than the "average" described by Vollenwinder and Kerekes (1980). Kerekes (1980) and Janus and Vollenweider (1981) showed among 18 lakes in Atlantic Canada that Freshwater Lake, along with two other clear-water lakes receiving anthropogenic phosphorus, had higher than average chlorophyll-a response to total phosphorus (above the OECD relationship), while the 15 pristine lakes, free from direct human influence, all show average or below average chlorophyll-a response to total phosphorus (Fig 8).

The number of phytoplankton cells/ℓ in an integrated sample from Freshwater Lake (29 June, 1976) was 2.05 x 10^5. The most common species present was the xanthophyte *Chlorochromonas minuta* (9.77 x 10^4 cells/1), a species which con-

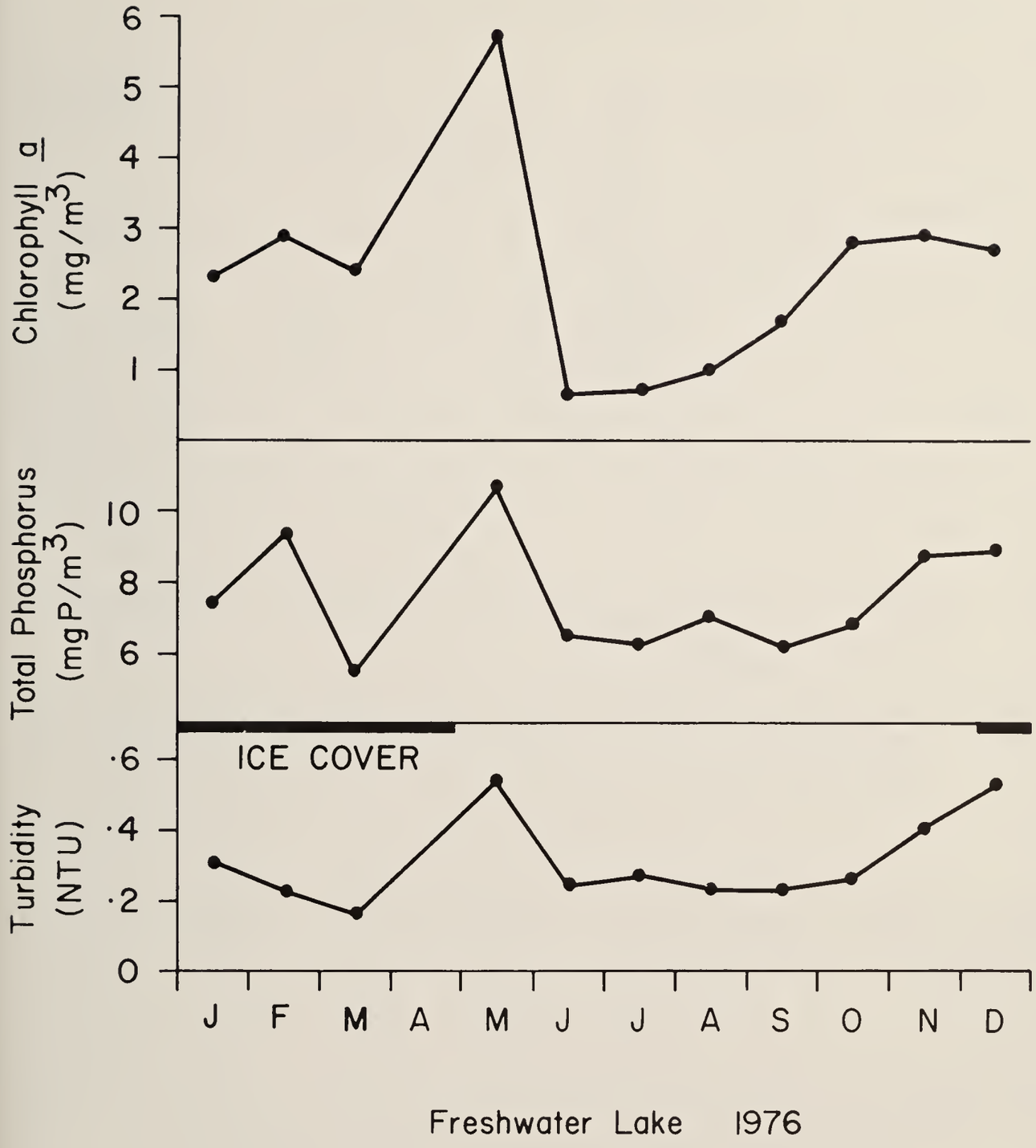

Fig 6. Mean monthly values of turbidity, total phosphorus and chlorophyll-a in Freshwater Lake, in 1976.

tributes to the spring phytoplankton bloom in Lake Mendota (Hutchinson 1967) and may well be responsible for a large part of the high spring chlorophyll-a concentration in Freshwater Lake. Two of the common diatoms, *Cyclotella meneghiniena* (4.31×10^4 cells/1) and *Synedra delicatissima* (2.27×10^5 cells/1), are also known to contribute to spring phytoplankton blooms.

The lake also supports dense growth of submergent aquatic vegetation at the western end in small sheltered embayments with mud bottoms. Twenty-two aquatic plant species were recorded in Freshwater Lake on August, 1976, including *Chara globularis*, five species of *Potamogeton* and two species of *Myriophyllum* (Davis and Wilson 1979).

The trophic characteristics of Freshwater Lake indicate that the lake is in transition between an oligotrophic and a mesotrophic state. According to the "fixed boundary system" for trophic categories developed in the OECD Eutrophication

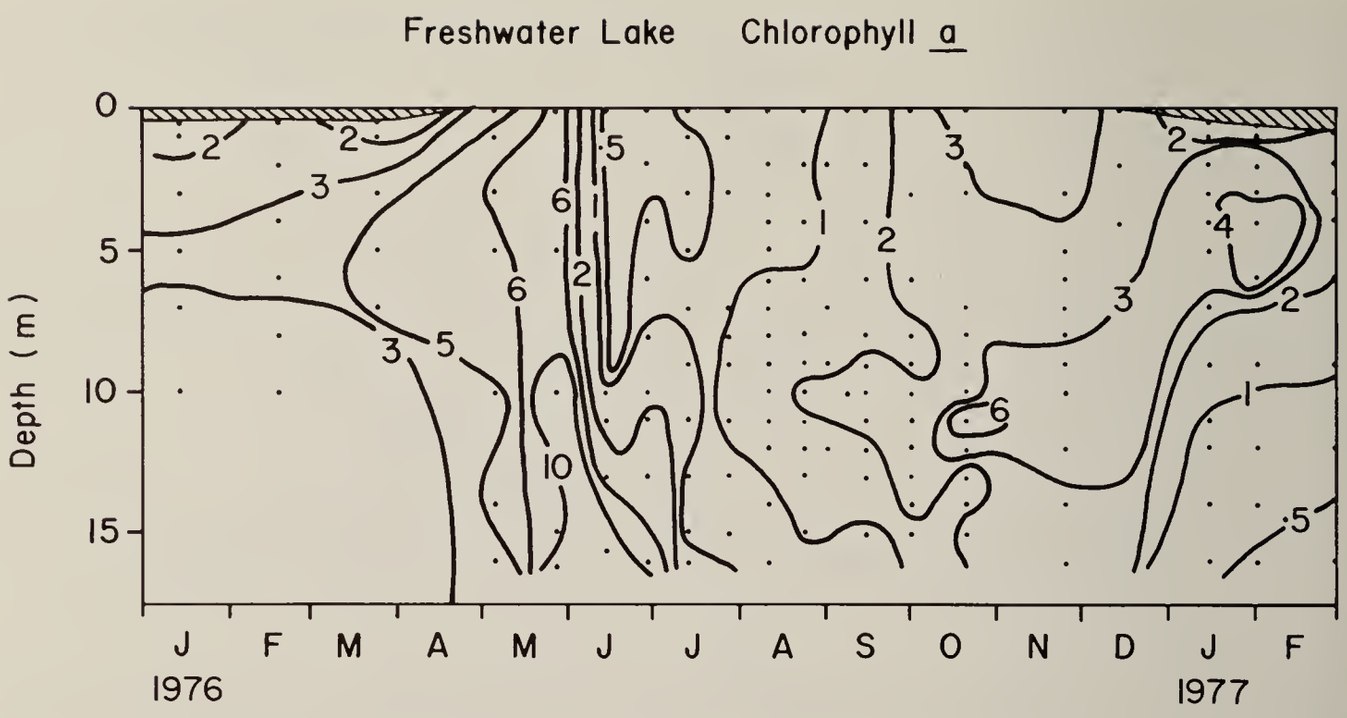

Fig 7. Isopleth of chlorophyll-a concentration (mg Chl/m^3) in Freshwater Lake. See Fig. 2.

Table II. Proposed boundary values for trophic categories (fixed boundary system) based on total phosphorus, chlorophyll-a concentrations and Secchi disc transparency. After Vollenweider and Kerekes (1981).

	Variable (mg/m^3)			Secchi depth (m)	
Trophic Category	$\overline{[P]}_\lambda$	$\overline{[Chl]}$	$\overset{max}{[Chl]}$	$\overline{[Sec]}_y$	$\overset{min}{[Sec]}_y$
ultra-oligotrophic	4.0	1.0	2.5	9.0	6.0
oligotrophic	10.0	2.5	8.0	6.0	3.0
mesotrophic	10—35	2.5—8	8—25	6—3	3—1.5
eutrophic	25—100	8—25	25—75	3—1.5	1.5—0.7
hypertrophic	100	25	75	1.5	0.7

Program (Table II), the lake could be considered as oligotrophic based on annual mean total phosphorus, Secchi depth and peak chlorophyll, and as oligo-mesotrophic based on annual mean chlorophyll. The hypolimnetic oxygen depletion, the relatively high abundance of several species of algae often associated with a higher trophic condition and the relatively dense growth of macrophytes all indicate a higher-than-oligotrophic condition in Freshwater Lake.

The transitional nature of Freshwater Lake between oligotrophy and mesotrophy is also reflected in trophic characteristics expressed in terms of probability, also developed in the OECD Eutrophication Programme. The total phosphorus value of 7.5 mg/m^3 has an attached probability of 22% for ultra-oligotrophic, 65% for oligotrophic, 13% for mesotrophic (Fig 9). The annual mean chlorophyll (2.5 mg/m^3) implies probability of 6% for ultra-oligotrophic, 50% for oligotrophic, 42% for mesotrophic and 2% for eutrophic; for peak chlorophyll (6.4 mg/m^3) 58% for oligotrophic, 36% for mesotrophic, 5% for eutrophic and 1% for hypertrophic conditions.

Overall, I believe that Freshwater Lake is best classified as oligo-mesotrophic with a definite tendency toward mesotrophy. This is in sharp contrast to the clearly

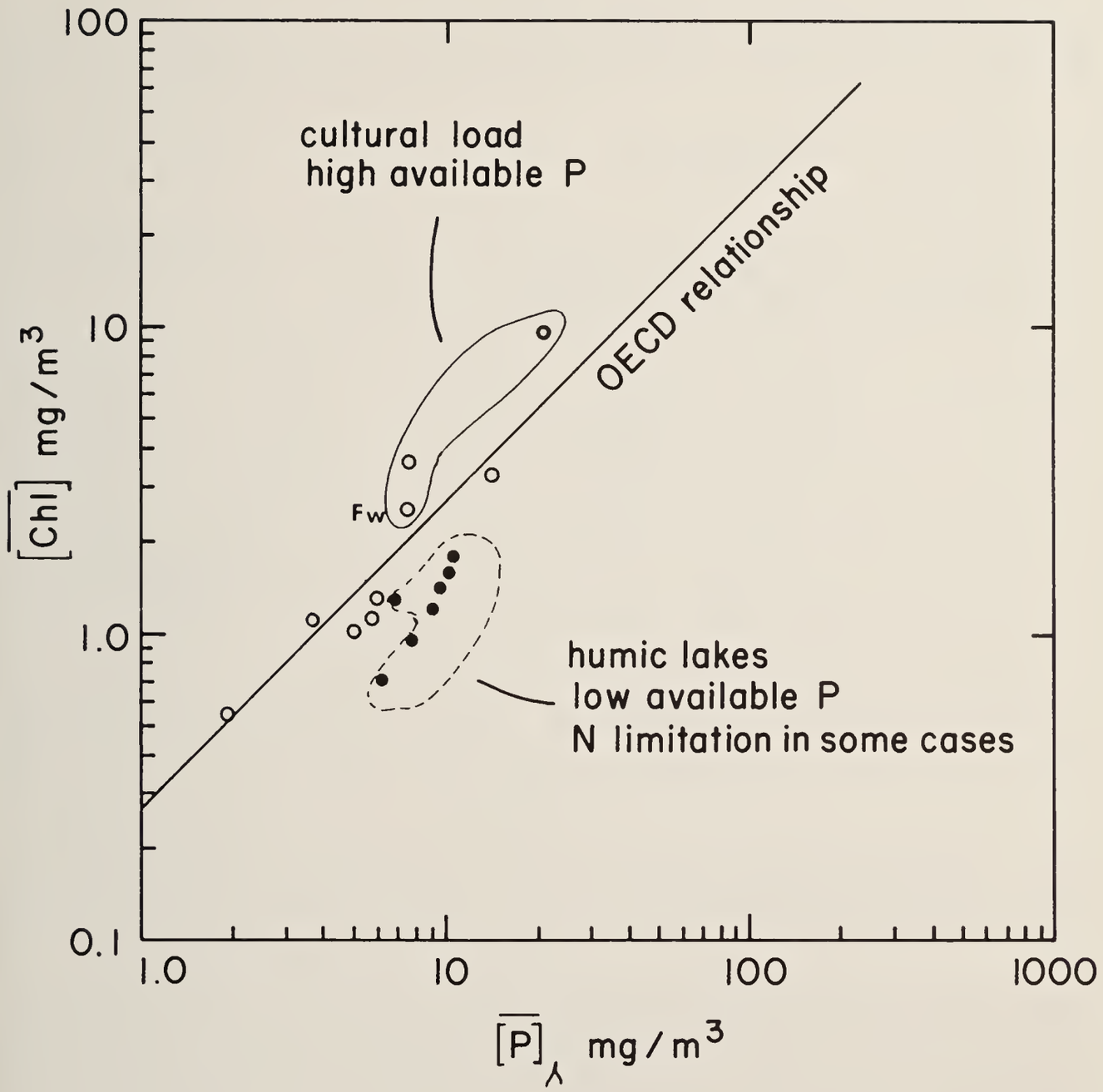

Fig 8. Annual mean chlorophyll-a in relation to annual mean total phosphorus concentration in selected lakes in the Atlantic Region of Canada. Freshwater Lake is indicated by the letters FW (after Kerekes 1980).

oligotrophic conditions found in two pristine, undisturbed lakes nearby (Kerekes *et al.*, 1981). It is not possible (see below) to separate the additional natural phosphorus contribution (sea spray) from the anthropogenic contribution (i.e., lawn fertilizers, septic tank leakage). However, it is safe to conclude that without the anthropogenic phosphorus addition, Freshwater Lake would be closer to the oligotrophy, which is the management objective for this particular lake.

Estimation of Loads of Natural and Existing Anthropogenic Phosphorus

Considering the estimated inflow total phosphorus concentration of 13.7 mg/1, it can be assumed that without the contribution of the existing diffuse anthropogenic load and direct sea spray, the total phosphorus concentration in the lake would be about 6 mg P/m^3, like those of two undisturbed pristine lakes nearby. Using this value and the value for total phosphorus concentration in the lake, the annual

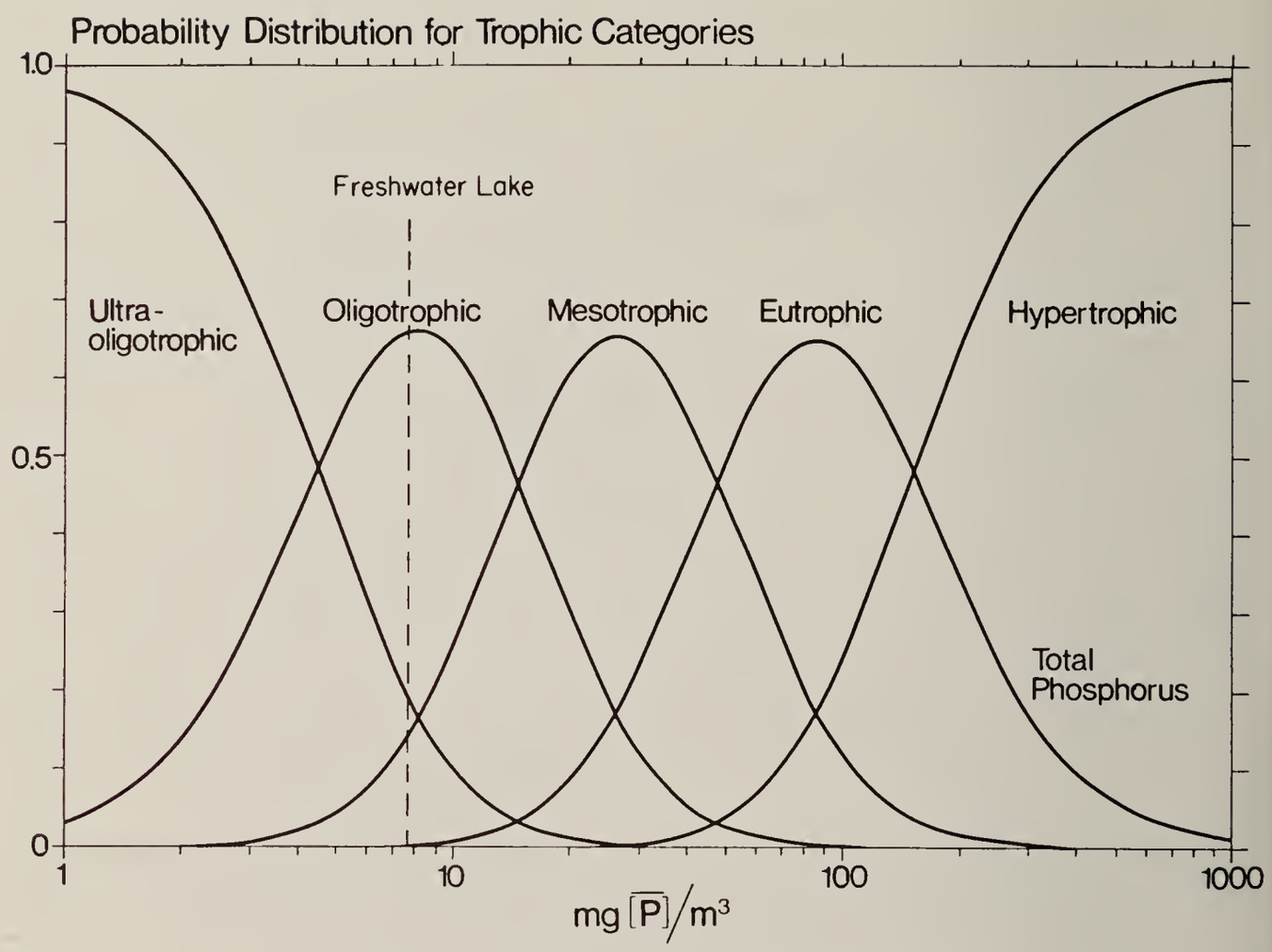

Fig 9. Predicted trophic conditions in terms of probability (5 trophic categories) for annual mean total phosphorus concentrations (after Vollenweider and Kerekes, 1981).

natural (edaphic) background total phosphorus load and the total annual anthropogenic (plus sea spray) phosphorus load can be calculated (Table III). It is reasonable to assume that the anthropogenic phosphorus is proportionately more available biologically than is the natural, phosphorus load. This may explain why the lake has a higher than average chlorophyll-*a* indicated previously (Fig 8).

The Estimated Impact of Phosphorus from Secondary Sewage Treatment.

The planners estimate that the proposed secondary treatment facility would yield 2.16 kg total phosphorus to Freshwater Lake. The proposed facility would only operate during summer when the lake is thermally stratified and water renewal minimal. It would therefore be misleading to consider the impact of additional total phosphorus load on an average, annual basis. Instead the expected response should be examined as it affects the epilimnion during the summer.

During summer 2.16 kg P added to the mixed layer (2.19×10^7 m³) would increase the epilimnetic total phosphorus concentration by 1.1 mg P/m³ (Table III). (On an average annual basis the total phosphorus concentration in the lake would increase only by 0.29 mg P/m³). This additional phosphorus however is in a form highly available for algal growth. According to the relationship of inorganic phosphorus and total phosphorus relationship given in the OECD Eutrophication study (Vollenweider and Kerekes 1980), the 1.1 mg/m³ of secondary-treatment phosphorus is approximately equal to 4.0 mg/m³ of total phosphorus under phosphorus concentration levels applicable to Freshwater Lake. By substituting the

Table III. Selected trophic and hydrological features and phosphorus loading estimates of Freshwater Lake, Nova Scotia. Abbreviations are given in methods.

	Existing Conditions	Natural (edaphic) Conditions	Expected Epilimnetic Concentration After Development
$[\overline{P}]_\lambda$ mg/m^3	7.5	6.0	*8.6
$[\overline{P}]_i$, mg/m^3	13.7	10.9	—
L(P) mg/m^2/y	132.7	105.6	—
Annual total phosphorus load kg/y	56.0	44.6	—
Anthropogenic total phosphorus load kg/y	**11.4	—	(13.56)
T(w) y	.67	.67	—
q_a m/y	9.69	9.69	—
$[\overline{Chl}]$ mg/m^3	2.5	1.6	*3.8
$[\overset{max}{Chl}]$ mg/m^3	6.4	4.2	*9.8

*summer epilimnetic value
**includes sea spray

latter value to the phosphorus-chlorophyll-a relationships (Vollenweider and Kerekes 1980), the expected increase in chlorophyll and peak chlorophyll would be 1.3 and 3.5 mg/m^3 respectively (Table III).

These estimated chlorophyll values would put the lake into mesotrophic category. This is based on the assumption that the lake would respond "normally" without a shift in algal (chlorophyll) response.

The foregoing discussion would apply for the lake as a whole. Close to the outflow of the secondary treatment discharge in a relatively well sheltered, shallow part of the lake, a more dense, nuisance-type algal response and macrophyte growth could be expected.

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THE DEVELOPMENT OF AGRICULTURAL ENTOMOLOGY IN NOVA SCOTIA[1]

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This paper traces the history of entomology in Nova Scotia. Prior to the 1880's published works were mainly taxonomic listings by gifted amateurs and scattered recommendations on pest control by writers unskilled in the applied field of entomology. Beginning in the 1880's there followed rapid developments in entomological education, research in pest control, and the building of educational facilities. Modern pest control had its inception, in the early 20th century, in the control of outbreaks of such pests as the brown-tail moth, *Nygmia phaerrohoea* Don., which soon expanded into the control of fruit pests. Fruit insect research has, since then, been the main area of entomological endeavour. Until the 1940's the major research effort lay in testing a large number of combination sprays and in the study of the biology of the insect pests. After 1940 the emphasis shifted to an ecological approach in an attempt to integrate the benefits of chemical treatments and the benefits from natural enemies.

Cet article retrace l'historique de l'entomologie en Nouvelle-Ecosse. Avant les anneés 1880, les travaux publiés regroupaient principalement des listes taxonomiques écrites par les amateurs de talent, ainsi que quelques recommendations concernant le contrôle des insects par des non spécialistes du domaine appliqué de l'entomologie. A partir de 1880, des developpements rapides se sont manifestés dans les domaines de l'éducation entomologique, de la recherche sur le contrôle des insectes et la Construction de maisons d'instruction. Au début de 20^{e} siècle, le contrôle des vagues d'insectes nuisables tel que le papillon de nuit à gueue brune, *Nygmia phaerrhoea* Don., a marqué le commencement des méthodes modernes de contrôle des insects. Ces méthodes se répandirent au contrôle des insects s'attaquent aux fruits. Depuis ce temps, les travaux concernant les insectes s'attaquent aux fruits représentent le domaine principal de la recherche entomologique. Jusqu'aux anneés 1940, l'effort principal de recherche a porté sur un test d'un grand nombre de combinaisons d'aérosols et sur l'étude de la biologie des insects nuisibles. Après 1940, l'approche écologique a été accentuée dans le but d'integrer des traitements chimiques et ceux des ennemis naturels.

Introduction

Insects, from the earliest times to the present day, have exerted a profound influence on humans. The damage they cause, the discomfort of their attacks, and other problems, such as the carrying of disease, have long focused attention upon them. On the positive side their beauty and such useful by-products as silk and honey have quickened attention since the cave walls served as an art surface. The science of entomology, not of extreme age in any part of the world, in Nova Scotia dates back to little over a century.

The object of this account is to trace developments in Nova Scotia. In the interest of clarity a strict adherence to chronology has been avoided as parts of the subject might be too widely separated by descriptions on concurrent events. For example, Paris Green, first used for the Colorado potato beetle, *Leptinotarsa decemlineata* Say, in 1882 continued its historic impact on other pests late into the 20th century. During that interval many other events of importance took place.

To give credits for all historical details has been difficult. On some occasions material derived from a number of sources, in a sense, had become common knowledge. Also, in searching for information, it was not the intent of the writer to evaluate research as such. Quotations or references are, therefore, meant only to reveal some historical detail or trend and most of these are in the nature of eye-witness reporting.

[1] Contribution of the Acadian Entomological Society

*Retired from the Entomological Section

Origins in Europe and North America

The following very abbreviated outline of entomology in Europe and North America before about 1800 is intended to give a perspective to developments in Nova Scotia as part of the continuing growth of the science. The next few paragraphs dealing with the background in Europe are synopsized mainly from a remarkable paper by Lochhead (1919).

The earliest references to insects in the Mediterranean area, not of a scientific nature, are to be found in such sources as the Old Testament and in the sculptured stone images of scarab beetles in Egypt before the year 3600 B.C. The Egyptians, in their search for medicines, doubtless made observations on insects but left no written record of them. The earliest written records on insects in Europe of a scientific nature are those of Aristotle (384 B.C.—322 B.C.). Lochhead says of him, "These [parts of Aristotle's papers] reveal the many sided nature of his activities, for he was not only a collector and classifier, but also a morphologist and inductive philosopher. He studied the life histories of many insects, he made many dissections and resolved the organs into tissues. His classification of insects, although based largely on external features, remained unimproved for more than 2000 years, and his generalizations contained ideas of evolution from the simplest to the highest organisms in nature". Quoting from a Professor Sundervall, for whom no source is indicated, Lochhead (1919) says, "Professor Sundervall estimates that Aristotle indicated and described about 60 species of insects and arachnids and about 24 species of crustaceans and annelids". It was pointed out by Lochhead that, despite large numbers of errors and crudities, Aristotle's valuable work has stood the test of time.

After Aristotle there appears to have been no significant contribution to naturalist thought until Pliny the Elder's (23 A.D.—79 A.D.) voluminous works appeared. Pliny, a naval man and a historian, attempted to compile all previous writings on nature. He combined a great deal of fancy with fact and added nothing new. His classification system was deemed by Lochhead to be inferior to that of Aristotle, although he adopted the latter's system in the case of insects.

For a long time after Pliny the Elder, i.e. during the Dark and then the Middle Ages, the study of nature was discouraged and largely neglected. Fortunately the lore of nature in the practices of farmers and gardeners was passed down as practical knowledge which provided a basis when studies on nature were revived at the time of the renaissance. Entomology had its more modern origin as a science with this background. It was made possible by the invention of the microscope without which the science of entomology was virtually impossible.

Space limits mention of but few of those Europeans who, beginning in the seventeenth century, built the foundations for all later entomology. Among the more interesting as well as more important are Malpighi (1628—1694) and Swammerdam (1637—1680). They merit special mention because of their remarkable contributions to the earlier studies of insect anatomy. Overlapping these two men in time, Valisnieri (1661—1730) is of special interest to applied entomology as the first to appreciate the nature of parasitism. It was he who first observed that parasite larvae originate in a host from eggs laid by an adult insect. Linnaeus (1707—1778) is famous enough to be immortal for his invention of binomial nomenclature, even if he had not made his huge contributions to classification.

It might be thought inevitable, after Valisnieri's observations, to expect a considerable study of insect parasitism in Europe. But it was not until 1840 that the principle of controlling an insect population by parasite introductions was demonstrated. In that year Boisgiraud of Poitiers in France introduced the climbing ground beetle, *Calasoma sycophanta* L., into his home town to rid the poplar trees

there of the gypsy moth, *Porthetria dispar* (L.). He also destroyed a population of earwigs in his own garden by bringing in the beetle, *Ocyphus olens* Muller. It is of interest to note that *C. sycophanta* was one of the natural enemies liberated in Nova Scotia between 1912 and 1915 in the attempt to achieve control of the brown-tail moth *Nygmia phaeorrhoea* Don.

Reference to what may be the earliest recorded instance of the practice of spraying was noted by Macoun (1901). He spoke of a formula, published in 1763, for using tobacco against plant lice, but did not say where. The application was made by means of a syringe with its "nose" pierced with about a thousand holes. The syringe was filled with water and lime, to which was added finely powdered tobacco. This remedy appears to have more merit than those in the following note, typical, no doubt, of many that were recommended to gentlemen farmers in the 18th century. In Weston's "*Tracts on Practical Agriculture and Gardening*", published in England, (see ref. list, A Country Gentleman 1769), the suggested controls for "white" flies on strawberries and roses are unusual, to say the least. The plants were first to be watered and then brimstone or tobacco dust stewn upon them. The picture of the "electric machine" to apply brimstone, pepper, snuff, tobacco, and quick lime is not at all clear. Also the boring of holes into trees and the filling of them with quicksilver, which was highly touted, appears to have had little to recommend it. The use of electricity, which was particularly favoured, was said to stimulate plant growth as well.

Moving from Europe to North America we find entomology in a decidedly embryonic state at the beginning of the 19th century. This conclusion and much of what follows about early United States and Canadian entomology, except where specific references are given, was synopsized from Webster (1895). Circumstances at the turn of the century provided little opportunity for collectors, or applied entomologists, to have their material identified on this continent. Hampered by lack of experts in taxonomy, entomologists sought assistance in England and France. The net result was that most of the new species discovered in North America were described in foreign publications. By the first of the 19th century there had been only 2 papers written that dealt entirely with American species, and these were published in Europe.

Truly North American entomology began with Thomas Say (1787—1834) who, as the first great taxonomist on this continent, has been called the "Father of American Entomology". Thaddeus William Harris (1795—1855) also made large contributions to taxonomy, but he is best known for his work in applied entomology. His book, "Insects Injurious to Vegetation", did for applied entomology what Say had done for taxonomy. These are but two special examples of men who, as first in their fields, led the way to the present level of entomology on this continent.

Entomology in Canada, influenced by contemporary work in the United States, was developing its own brand of the science by the middle of the last century. It began to come into its own in 1837, when the Rev. William Kirby had his descriptions of 447 species, mainly Coleoptera, included in Sir John Richardson's "Fauna Borealis-Americana". The material was later revised by Bethune and published in the Canadian Entomologist. A beginning was also made in the applied field by Prof. H.Y. Hind of Trinity College, Toronto, Ont. in 1857. His "Essay on Insects and Diseases of Wheat", issued in that year, was the first entomological work published with the financial backing of the Canadian Government.

Entomology, developing through the contributions of a number of private individuals by the mid-century, was facing the need for a strictly entomological outlet. This objective was moved one step closer when the *Canadian Naturalist and Geologist*, in 1862 published a list of 30 entomologists in Canada. It was a nucleus

drawn from this group which organized the Canadian Entomological Society in 1863. The new society prepared to publish its journal, *The Canadian Entomologist*, the first issue of which appeared in 1869. Three years later the Canadian Entomological Society was incorporated as the Entomological Society of Ontario to serve as the parent society to a number of affiliates. This status was maintained until the Entomological Society of Canada was created in 1950.

The Department of Agriculture, as proposed in 1867 was formalized by an act of parliament in 1869. The new department rapidly improved government services in many respects, not the least of which for entomology was the appointment of Dr. James Fletcher as Dominion Entomologist in 1884, unpaid then but made permanent in 1885 (Hewitt 1912).

Fletcher himself explained to the assembled fruit growers in Nova Scotia in 1886, "It was decided that the appointment should be a purely honorary one; in fact it was an experiment to test the value of such investigations, to the country at large. The decision was, I believe, a wise one . . . . " (Fletcher 1886). In retrospect no one will argue the wisdom of having a trained man to look after the entire range of pest problems for the Dominion. Webster (1895) provided an apt simile when he told the Entomological Society of Ontario, "It is like attempting to lower Niagara River by dipping the water out of Lake Erie with a teaspoon. You ought to have Dr. Fletcher, and at least a corps of half a dozen well-trained and experienced entomologists and God speed the day when you may have them".

When by another act of parliament, in 1886, the first five Experimental Farms were established, Fletcher took up office at the Central Experimental Farm in Ottawa as Dominion Entomologist and Botanist. He carried those responsibilities until his death in 1909. Upon the appointment of C. Gordon Hewitt the divisions were separated to handle the greatly expanded number of problems. Three problems were of particular interest to Nova Scotia. These were: the Colorado potato beetle *L. decemlineata*, the brown-tail moth *N. phaeorrhoea*, and the San Jose scale *Aspidiosus perniciosus* Comstock. The latter continued to be a threat only, until it finally gained entry to Nova Scotia in 1912.

Developments Originating Before 1880 in Nova Scotia

Taxonomy and Collections in Nova Scotia

The rather slow beginnings of entomology in this province had their origins in the taxonomic interests of non-government intellectuals. Though fundamental to applied entomology, the science of taxonomy in Nova Scotia has, unfortunately, never been the recipient of federal government support.

Most of the better entomological work in the earlier days was in the collecting and classification of insects. Pickett and Payne (1939) provided a valuable historical summary of taxonomy up to about 1880 in their review paper. They say; "About 1839 a Lieutenant Redmond made a collection of Nova Scotian insects, mostly Diptera, which are housed in the British Museum. In 1864 Thomas Belt collected Lepidoptera in the vicinity of Halifax. In the years 1870-1879, J. Mathew Jones made a collection of Coleoptera, Hymenoptera and Lepidoptera in this province. In 1879, the Rev. C.J.S. Bethune compiled a list of 46 species of Nova Scotia butterflies. It is thought that the latter collection was made in the vicinity of Halifax in the late 1800's. Since 1900 more extensive collections have been made by numerous workers. Additional information on these may be obtained by reference to a paper by Brittain in 1918".

It will not, one hopes, minimize the contributions of the private collectors if the titles, taxonomic groups collected and the geographic areas of collecting are omitted. Unfortunately, the fate of most of these collections is unknown. A brief but

pertinent discussion of personages and the material collected may be found in Ferguson (1954). In addition to those discussed or to be discussed there were such names as E. Chesley Allen, C.E. Gooderham and Margaret Brown. The day of the private collector began to pass during the war years of 1914-1918. Both the *Proceedings of the Nova Scotia Institute of Science* and the *Proceedings of the Nova Scotia Entomological* Society, later the *Proceedings of the Acadian Entomological Society*, served as vehicles for their publications.

The collection started by Prof. H.W. Smith in Truro after 1886 was intended mainly for student use and no serious attempt to build a collection was made until after the Agricultural College was founded in 1905. By 1918 most of the identified reference material, according to Brittain (1918), had been collected after 1915. It continued to grow into a fine, well-referenced collection under the direction of H.G. Payne until its tragic loss by fire in 1946.

An important collection of Nova Scotia species was also built up over many years at the Annapolis Royal Entomological Laboratory. Owing to the interests of G.E. Sanders the collection contained some 3000 specimens by 1919. It was greatly expanded later by F.C. Gilliat and still further by H.T. Stultz. The collection was moved to the new Science Service Laboratory in Kentville in 1951. The current number of specimens in the Kentville collection is unknown but is probably in excess of 10,000.

The largest and best collection today is maintained in the Nova Scotia Museum of Science in Halifax. It was begun shortly after 1899 when Harry Piers, an orthopterist of note, became curator of the museum. Brittain (1918) says that the museum collection at that date consisted of about 2000 specimens with full data, all collected after 1900. It started with the purchase in 1906 and 1909 of the 1049 specimens of Lepidoptera upon which the paper by Perrin and Russell (1911) was based. Two more additions were made, one of Lepidoptera by Lucy C. Eaton and another by A.H.C. Richards. Piers, who had extensive interests, evidently maintained his connections with entomology, publishing several papers after taking office. One of them was on Formicidae (Piers, 1923). There was, however, no other significant contribution to the collection until the period 1934 to 1946 when J.H. McDunnough, Chief of the Division of Systematic Entomology in Ottawa collected Lepidoptera in Nova Scotia. The collection of Lepidoptera was greatly expanded by D.C. Ferguson who had responsibility for the Museum collection between 1946 and 1965. When Ferguson was joined on the staff by McDunnough, who worked in cooperation with Ferguson between 1950 and 1962, Nova Scotia benefited greatly. Their investigations on the fauna of Lepidoptera have given us an extensive knowledge of identities and distribution of this order in Nova Scotia.

The size of the collection in the museum has continued to grow until, as of 1981, it contains in excess of 325,000 specimens, a high proportion of which are Lepidoptera, mostly Nearctic, but other orders are well represented. Barry Wright, who took charge of the Museum collection in 1965, has added his large private collection of Palearctic and Nearctic Coleophoridae. His comprehensive paper on the Coleophoridae of America, north of Mexico, is soon to be published.

Status of Applied Entomology, 1865-1885

When the Provincial Government was reorganized in 1864 it brought all the Agricultural Societies under common control but did little directly for entomology. By initiating the *Nova Scotia Journal of Agriculture* in 1865 as a vehicle for the dissemination of agricultural information to farmers, some interest in insect control was promoted. The *Journal* was a periodical in newspaper form that outlasted the Board of Agriculture, and its successor, the Central Board of Agriculture. It ceased publishing in 1885.

The remedies contained in the *Journal of Agriculture* are, perhaps, more interesting as a record of control concepts than of successful remedies. The quotation below (from Vol. I) may seem amusing today with our greater sophistication. "The turnip crops are liable to various maladies. The turnip fly, *Haltica nemorum*, is its present greatest pest. This insect attacks the infant plant so soon as it expands its cotyledons and sometimes destroys whole fields. Various remedies have been proposed, such as burning the stubble, applications of odorous manure distasteful to the fly, mixing seeds with sulphur, excessively thick sowing in the drill to provide for the insect and have a crop left, steeping the seeds in water to promote rapid germination, sowing hot lime over the young plants, watering every other day five to six times if necessary, catching flies in tarred cloth, fumigation by burning rubbish to windward of the field, drawing freshly painted boards over the field, an application of wormwood, powdered sulphur strewn over the seed bed, snuff, heavy rolling, etc. We believe, however, that the only remedy is to dust the terminal leaves of the young turnip plants with quick lime, a bushel of which is sufficient to dust an acre. Lime and road dust proved good substitutes, the latter probably from the lime it contains. Powdered plaster would answer better. These substances should be applied in the morning when the dew is on the leaves".

The practical value of the suggestions is not great, but they do provide an excellent picture of the untested remedies offered to farmers. The author did, however, make the earliest known references to the use of sulphur as an insecticide to have been published in this province. It has since been shown in various areas of the continent that sulphur has insecticidal properties. Kelsall (1922) claimed it increased the toxicity of lead arsenate. In the literature there are also a number of references to its adverse effects on natural enemies, some by direct poisoning and others through distortion of their sense organs.

Losses from insects in those earlier years must simply have been accepted as unavoidable and natural. Seemingly, government sources were not sufficiently interested to take action until it was forced upon them by the discovery that the Colorado potato beetle, *L. decemlineata* had gained entry into the province. That one catastrophe, in particular, served to precipitate developments in government participation in the techniques of agriculture. Presumably the authorities were already making plans to take part in agricultural education, as many changes followed shortly after the discovery of the potato beetles on the crops.

Heavy outbreaks of the new pest occurred in 1882 just before the Central Board of Agriculture was replaced by the Office of the Secretary for Agriculture (which was set up in 1885). The potato beetle outbreak was a startling development for farmers. It was also the first instance in which government authorities in Nova Scotia took an active part in organizing the control of a pest. *The Journal of Argriculture* has this to say: "Reports have been made in the newspapers and otherwise of the occurrence of the Colorado beetle on the potato crops of Nova Scotia, particularly, in the countries of Cumberland, Pictou, and Kings. It is probable that in some if not all cases some pests other than the great destroyer have been found. We shall feel much obliged if the persons who have the opportunity will kindly send us dead specimens for examination. The beetle can be humanely killed by dropping into alcohol or chloroform and will travel in a pill box."

The Annual Report of the Central Board in 1883 warned, "During the past year the so called Colorado potato beetle, which has been so destructive to the potato crop in other parts of America, has begun to show itself in Nova Scotia. The Board has collected information as to the best means of destroying it which will be diffused among farmers at the proper season . . . . It is believed that vigilance on the part of the potato grower in carrying out these instructions will effectually prevent the spread of this pest to any serious extent in this province". A letter to the editor

of the *Journal of Agriculture* in 1883 says very few potatoes were planted as people were afraid of the bug. Another said the potato beetle was causing consternation.

Pickett and Payne (1939), having quoted from the Report of the Secretary to the Central Board of Agriculture, go on to say with faint, but justified irony, "From the above it would appear that the government officials in those days had the same fond hopes as those cherished by many of their modern counterparts in thinking that the recommended control measures would be carried out precisely".

The Role of Paris Green in Nova Scotia

The counselling distributed to farmers was not available to the writer. No doubt it was much the same as that in Vol. 4 of the *Journal of Agriculture*. In exhorting farmers to use Paris Green or London Purple, the news item first suggested as very effective the jarring of the beetles into a pail, a method used in small gardens for a long time. The instruction to apply Paris Green was an historic development signifying a great step forward in the use of poisons. It might be easy now to underrate the importance of the first really effective stomach poison, which was also the introduction in Nova Scotia of arsenicals as some of the most widely used insecticides.

Paris Green continued in popularity at least into the 1930's, or later, for potatoes as well as in poisoned baits. In 1941 it was still fourth in the volume of poisonous materials produced in the United States. This insecticide is a complex combination of copper metarsenite and copper acetate, which had its first use as a poison in the United States for the potato beetle. London Purple, as registered today, is a different product from the earlier one. The older material was an industrial by-product of variable arsenic content obtained from the manufacture of dyes. Its effects were unpredictable.

Compared to previously available poisons Paris Green was an outstanding insecticide, in spite of the dangers to foliage. James Fletcher, Dominion Entomologist, speaking before the Nova Scotia Fruit Growers in 1886 then considered the potato beetle to be the most severe pest problem faced by farmers in Nova Scotia. He recommended (Fletcher 1886) treatments with Paris Green, and also suggested the same poison for the codling moth *Laspeyresia pomonella* (L.) and the plum curculio, *Conotrachelus nenupar* (Hbst.). Nevertheless he warned that Paris Green should not be used at strengths greater than a tablespoonful to a barrel of water; otherwise, the damage to the tree might be greater than from the unchecked pests. At this small dosage the cankerworm, *Alsophila pometaria* (Harr.), was difficult to control. To make the poison less phytotoxic the addition of flour or plaster of Paris was recommended as a diluent in both the dry and liquid preparations.

Other Poisons Before 1880

Kerosene was considerably less significant in control recommendations, but it was long deemed a useful insecticide. Probably its insecticidal properties were known for some years before an anonymous writer (probably the editor) asked in *The Journal of Agriculture* of 1885 (Vol. 4), and answered his rhetorical question, "How few of us are there who would not give anything, as they say, to know how to keep away the cabbage fly from their seed beds, yet about a tablespoonful of coal oil put into a garden pot of water, sprinkled over the seed bed when the little jumping beetle is noticed as having appeared, will instantly kill the whole brood. Coal oil kills scale insects . . . .". Added is a warning that, although the oil will kill all vermin on the apple tree, it will destroy the tree. This readily available agent continued in use for many years and had some limited application even in the twentieth century. Fletcher, in his talk to the Fruit Growers in 1886, highly recommended it for scale insect control on apple trees along with the suggestion it be emulsified with sour milk or whale oil soap and then diluted.

Another insecticide that was well known for a time, even if less effective, was whale oil. It was first used in Massachussetts, but in Nova Scotia was most commonly used as a soap for wetting other poisons or as an emulsifier. This oil was recommended in 1872 for the garden slug and the rose beetle, but as the second remedy. *The Journal of Agriculture* was not too enthusiastic when it suggested, "All kinds of remedies have been proposed—whale soap, petroleum, etc., but the best thing is to set a boy to crush them by thumb and forefinger". Boys will be boys, but the method does not suggest itself as a favoured form of amusement.

Developments Originating 1880 - 1905

The Beginnings of Agricultural Education

The excitement in 1882 over the introduction of the potato beetle, which had marked the first instance of active participation by government authority in insect control, was followed by a series of moves into extension and education in general. The Central Board of Agriculture was dissolved in 1885 to be replaced by the Officer of the Secretary for Agriculture. The value of instructing farmers had been demonstrated by the potato beetle problem. It seems a reasonable assumption that by then it had been realized that a more informed farm population was an obvious economic advantage to Nova Scotia. Consequently, one of the first acts of the new office was to appoint a Lecturer in Agriculture in 1885, to hold office in the Provincial Normal College in Truro. The objective was to prepare teachers, in particular, to carry information on agricultural methods to rural areas. There were short courses for boys from the farm as well.

Prof. H.W. Smith was the first, and only, such appointee to hold that position. This he did until he was moved to the newly opened Nova Scotia Agricultural College in Truro in 1905. His teaching duties at the Normal College included chemistry, botany, zoology, veterinary medicine, entomology geology, physics, hygiene, and practical agriculture.

Almost immediately upon taking up office Prof. Smith found he was handicapped by lack of land for experimentation. His representations to the government to rectify the situation met with success. In July 1888, a piece of land which now constitutes part of the Nova Scotia Agricultural Farm was purchased.

Interest in the School of Agriculture at the Provincial Normal College, among other factors, was showing the need for an institution for agricultural instruction. Fruit growers were playing a part for, according to Dr. R.S. Longley (1963), their association had been pressing for the establishment of a School of Horticulture for some time before 1886. The government finally agreed with the rationale of investing in education. As a result, the School of Horticulture at Acadia University was opened for classes in 1892 - 1893 with E. E. Flavelle as Director. Three years later he was succeeded by Prof. F.C. Sears. Sears taught there until the school was closed and he was moved to the Nova Scotia Agricultural College in 1905.

The steps already taken in the appointment of Prof. Smith in 1885 and the purchase of land in 1888 were indications that science was coming to agriculture. But these events were only a part of general trends toward improved techniques in farming, education in the sciences, and in improved marketing knowledge in all of Canada. The concept of training young people in order to bring science to farming in Nova Scotia was receiving wide support by the 1890's. At that time the Nova Scotia Fruit Growers' Association was providing some of the more active support.

Plans for an agricultural college assumed concrete form in 1898 when the legislature passed "An Act to Provide for an Agricultural College to be built in Truro". The new facilities, which we know as the Nova Scotia Agricultural College, opened in 1905 with Prof. Melville Cuming as Principal and with Prof.Smith con-

tinuing on as Professor of Biology. Judging by his reports to the Secretary for Agriculture the reorganization had provided Smith with more time to write descriptive material on insect stages and life history. Such information was one of the main entomological needs of the times.

Plans had already been underway to build the College when H.G. Payne, previously mentioned in the section on taxonomy, assumed care of the insect collection and the extension work in entomology. These duties placed him in a logical position to play a major role in combatting an outbreak of the brown-tail moth, *N. phaeorrhoea*, a few years later.

Presumably the staff shared with Prof. Smith his views with respect to the need for an entomologist in the province. He had said as early as 1892 of such an appointment, "There is need of a good entomologist for the province who would devote his time and energy to the fruit growers and farmers of the province. Now if he were employed as Professor of Entomology in the Provincial School [meaning the School of Agriculture at the Normal College] he could visit these local schools and experimental stations and could have experiments conducted and by so doing, show farmers how to combat their numerous insect enemies etc. At the same time he could give instructions in this line to pupils of this local school". His wish was granted some twenty years later in the appointment of Dr. Robert Matheson in 1912.

The Role of the Nova Scotia Fruit Growers' Association

The rather sudden upsurge in agricultural organization across Canada, particularly after 1880, found expression in the activities of the Nova Scotian fruit growers. Because it has been typical of their organization we may safely assume that the group had been pressing for such changes as the setting up of the Office of the Secretary for Agriculture, the appointment of a Lecturer in Agriculture and in the planning for educational facilities in agriculture. Although Prof. H.W. Smith's duties included the teaching of entomology, the main source of practical information on the subject for a fairly long time was through the fruit growers' meetings and in their annual reports.

The Nova Scotia Fruit Growers' Association, first organized as the Fruit Growers' Association and International Show Society in 1863, issued its first published report in 1883. Succeeding annual reports drew much stronger attention to fruit growers' interests and, coincident with a wave of government participation in agriculture, emphasized the need to improve production methods. Certainly the government recommendations to use Paris Green for the potato beetle affected fruit growers who, being general farmers, were becoming more interested in insect control in general.

Without doubt the ravages of insects in orchards had concerned fruit growers long before their annual reports began to publish discussions of control measures. The honor of having had the first paper on orchard insects in Nova Scotia published under his name, however, goes to Mr. T. E. Smith, a nurseryman rather than an entomologist. His address was published in the 1884 report. However odd some of his comments may seem by modern standards, he gave his audience the best then available in his talk entitled, "How to destroy insects in orchards" (Smith 1884). Although his ideas were inaccurate, the information he presented is interesting and his sources somewhat a mystery. Possibly his facts were obtained from English sources such as Weston's Tracts on Practical Agriculture and Gardening published in 1769, mentioned in the introduction.

In discussing the control of the cankerworm, *Alsophila pometaria* Har., then, as now, a most important pest of apples Smith (1884) suggested the following remedies. One was to fasten a band of coarse cloth soaked in printer's ink around

the trunk of the tree. He also recommended Paris Green and London Purple mixed in the proportions of one part to seven hundred parts of water to be applied with a force pump or syringe. These arsenicals, Smith pointed out, would destroy the apple foliage if used at any stronger dosage. Also described briefly are the apple tree caterpillar (not identifiable), the tent caterpillars collectively (presumably *Malacosoma disstria* Hb. and *M. americana* Fab.), the codling moth *L. pomonella,* and the oystershell scale *L. ulmi*. The codling moth could be controlled by encouraging birds, by lighting bonfires to attract and destroy the moths, by picking up wormy apples, and by the banding of the tree trunks with cloth impregnated with printer's ink. Smith says of the oystershell scale: "An excellent wash is made by dissolving 2 lb. of potash in six to eight quarts of water, which may be applied with a mop about the latter part of May or the first of June. Large sums of money have been paid for this simple recipe". The "simple recipe" had no direct influence on the scale population at all. Research some 60 years later showed that it did allow the natural enemies to flourish and thus destroy the scale population. Belief in the use of whitewash, however, persisted for many years.

The impact of James Fletcher, Dominion Entomologist, on Entomology in Nova Scotia

The official appointment of Dr. James Fletcher by the Dominion Government in 1885 marked the beginning of federal involvement in entomology in Canada. It also coincided with the provincial appointment of a Lecturer in Agriculture in Truro. Following Fletcher's assumption of his duties the instructions for pest control began to be based on tested methods. Fletcher also cooperated in following years with provincial authorities by supplying technical papers on agricultural pests for inclusion in the Lecturer's reports to the Secretary for Agriculture. At that time little opportunity was available in Ottawa or in Nova Scotia for field experimentation. Presumably both men made use of tests made in Ontario and in the United States as well as those from such books as W.E. Saunders' "Insects Injurious to Fruit" published by Libby, New York.

The decision to invite a trained entomologist to speak to the assembled fruit growers in 1886 was a good one for the orchardists and, eventually, for entomology. The address he gave (Fletcher 1886) proved to be the beginning of the mutual liaison of farmers' experience with the research of plant pathologists, entomologists and chemists, which is a feature of spray practices in the Annapolis Valley to this day. After 1915, all recommendations for orchard pest control in Nova Scotia came through this liaison from tests in orchards.

The material covered by Fletcher (1886) in his historic address is much too lengthy for more than a brief synopsis. He showed the growers the importance of using measures based on knowledge of the life history and habits of the pests, knowing how to recognize them, being aware of the best spray materials, selecting sprays on the basis of feeding habits, finding ways to make the poisons safe to use, having some idea of the role of parasitism, etc. The information then available on how to render toxic materials safe for foliage was still rather primitive, although the poisons were very effective.

Development of Equipment for Applying Sprays

It is impossible to give a date for the first use of equipment in Nova Scotia for spraying plants. A few early instances of recommendations have been mentioned. Materials applied to plants in dust form must have been made with anything available such as a piece of cloth. There are early recommendations for using a watering can for liquid applications or by allowing poison mixtures to drip from a piece of cloth. Such were the rather primitive means of applying materials like

hellebore, pyrethrum, tobacco concoctions, and the miscellany recommended to small gardeners and the farmers alike. More serious attention began to be paid to methods of applying sprays to apple trees after Fletcher's (1886) first address, but there are earlier records. Some of our older citizens still recall the use of the mop as an applicator.

Frequent mention was made during the nineteenth century of the use of the "syringe" as an instrument for applying insecticides. This seems to have been any kind of pump which, when thrust into a pail of liquid delivered it with a small amount of force through a tube and nozzle. "Spraying", says Macoun in 1901, "is an old custom under a new name. While the word 'spraying' has been in use less than twenty years, the word 'syringe' was used long ago. It was when the liquids began to be used for extensive work that the expression 'to spray' superceded 'to syringe', although the latter is still used to a limited extent".

Some indication of the date of the first employment of wagon-mounted sprayers in the Annapolis Valley is provided in a letter written by Mr. R.W. Starr of Wolfeville and quoted by Macoun in 1901 as follows: "I can scarcely give dates as to when spraying was first adopted in this province, as the practise has grown up from small beginnings, with the fine rose watering pot and garden syringe using solutions of whale oil soap, tobacco, and hellebore to destroy currant and gooseberry worms and thrips on rose bushes. These methods were used by the Hon. C.R. Prescott as early as the 1840's at least . . . . In 1885 Mr. A.S. Harris . . . . got a small force pump and double orifice from New York. With this he sprayed his trees, using Paris Green, one teaspoonful to two quarts of water. This was so successful that the next year everyone who was troubled with the cankerworm provided himself with a pump and arsenites. Since then the spray has been continuous where needed, large pumps fitted to casks or tanks and placed upon wagons being used for this purpose. The first of these was gotten by myself in 1880. I used a brass cylinder lift and force pump with suction and delivery holes. With this I tried nearly every kind of nozzle made . . . ."

While general acceptance of the idea of spraying did not come without a good deal of resistance, the practice did make important strides after the 1880's. Power spraying developed rather slowly. Some idea of the standards of pressure needed were given by Mr. A. McNeill to the Fruit Grower's meeting in 1902. He pointed out (McNeill 1902) that it is difficult to maintain the 100 lb. pressure required and that spraying could never be properly done until the man at the pump handle could be dispensed with in favour of a power machine. "Even a hired man gets tired at the pump handle . . . ." After 1900 power sprayers were becoming more numerous, but in the memory of some older farmers, the barrel with its hand pump was not fully superceded by 1914.

Prof. P. J. Shaw, in his report to the Secretary for Agriculture for (Shaw 1911), gave a good indication of progress. "One of the greatest developments in spraying occurred last year in the change on the part of many growers from the hand pump outfit to the gasoline powered sprayers. One hundred and thirty of these power outfits are said to have been sold in the fruit district last season . . . . Aside from this [value of the engine for farm use] the power sprayer is likely to displace, in large measure, the hand outfit . . . ."

According to Kelsall (1939) spraying was fairly general practice by 1910, at which time there were still quite a few hand pump sprayers. By 1918 almost all growers were using powered sprayers. These remained fundamentally the same, except in the amount of spray delivered per minute, until the advent of air-blast sprayers about 1951.

Dusting with power-operated machines as a means of applying combination pesticides to orchards was widely practised for a time after 1918. When these ap-

plicators were first tested in Nova Scotia dusting already had a background of 50 years use in the United States. The practice never fully supplanted spraying in Nova Scotia. For reasons to be discussed, dusting began to lose popularity after 1924.

Just as the coming of age of the power sprayer with its gun or boom was a leap ahead in technique, the air-blast sprayers which began to take over after 1950 were an equally sensational advance. The first of these to be used in Nova Scotia was an Okanagan Mist Blower purchased in 1949 by Agriculture Canada for entomologists. With it came another British Columbia contribution, viz. the idea of concentrating materials in order to spray a great deal faster. Within a few years most of the growers had equipped their sprayers with air-blast attachments. These in turn were replaced in a few years by commercial models designed specifically for air-blast spraying.

The Beginnings of Insecticide-Fungicide Combinations

Paris Green, which had proven so effective for orchard pests beginning after 1880, was so dangerous to foliage that better combinations incorporating the "sovereign" remedy were being recommended soon after by Fletcher (1886). Some suggested additives helped but quite often the dosage of Paris Green had to be kept so low it was likely to be ineffective against certain leaf-eating insects. Consequently, it is not surprising that the use of Bordeaux mixture for apple trees received early support.

The full story of copper and sulphur based fungicides, mixed with various insecticides, would fill volumes. Each, however, played too large a part in the growth of control measures for fruit and vegetable pests to be dismissed without at least a brief resumé. Sulphur, according to Macoun (1901), had been recommended in England in 1821 against mildew on peaches. He also noted that W. E. Saunders had suggested to American experimenters the idea of testing liquid applications of it against apple scab, *Venturia inequalis* Wint. He recommended the boiling of quicklime and sulphur together. This material later became known in Nova Scotia under the name of lime-sulphur. It found popular use a little later than did Bordeaux mixture.

The fungicidal properties of copper sulphate which had been made safe by the addition of lime were discovered in France in 1886. The mixture was not well received in the United States until it was shown in Iowa in 1889 that it removed much of the danger of burning by arsenicals when used on potatoes. A few more years passed before copper fungicides were discussed at the Fruit Growers' meeting in 1892. One of the growers stated that copper sulphate precipitated with strong ammonia did not prevent Paris Green from burning apple foliage severely. Nevertheless a low lime bordeaux mixture suggested in 1893 continued in general use after that. The proportions were: copper sulphate, 4 lb; lime 4 lb; Paris Green, 4 oz; and water 50 gal. For the following few years most of the explanations of spraying dealt with means of preparing the mixture. In 1898, Prof. Sears reiterated with more effect that the adding of Paris Green to Bordeaux rendered the arsenic safer to use (Sears 1898). Some idea of the acceptance of spraying by that time is contained in his statement that most of the first class growers were now spraying. Judging by some contemporary remarks it *was* the "first class" growers and not the majority who were applying sprays regularly. Spraying with hand pumps was still such sheer labour that it was too unpleasant to accept readily. That limitation, and doubts of its value, held up more general acceptance of the practice. In addition, fear was expressed about the dangers of selling poison-treated fruit to the public. With the more general use of powered sprayers in the 1900's the aversion to spraying abated, particularly after it was understood what the Bordeaux - Paris

Green mixture was doing. The introduction of lead arsenate as a poison in 1895 also helped to reduce foliage and fruit damage.

The Bordeaux - Paris Green mixture, which had considerable popularity, was not an unmixed blessing. It did give good control of biting insects such as the codling moth and the cankerworm, along with fair control of apple scab. On the negative side it damaged the foliage and caused severe "russetting" of the fruit surface if used in the bloom period. Then, when lime-sulphur with lead arsenate was substituted in that period the finish of the fruit improved greatly. Unfortunately the combination reduced the crop. Some of the increased injury from either combination was a result of the heavier applications made possible by power spraying, although the reasons were not at first apparent.

Brittain's (1916) work, and then the studies made by staff of the Canada Agricultural Laboratory at the Dominion Entomological Laboratory at Annapolis Royal under G.E. Sanders, began to give the development of spray programs a scientific basis in orchard tests in Nova Scotia after 1915. Brittain's orchard studies in 1915 and 1916 saw the beginnings of an enormous amount of investigation on spray materials by government staff. These first plots by Brittain compared a number of lime-sulphur, soluble sulphur and copper-lime mixtures, each in combination with lead and calcium arsenate. The development of spray programs started by Brittain and taken over largely by federal employees after 1915 is the subject of much of the later parts of this outline. The various components will be discussed in the appropriate sections.

Developments Originating 1905 - 1915

Even before the Nova Scotia Agricultural College had opened its doors to students in 1905 there had been the start of an insect collection and Prof. Smith had taught entomology, among his many subjects. Smith (1892) had early expressed his belief (see p. 000) in the need for a full-time entomologist. The outbreak of the brown-tail moth, *N. phaeorrhoea,* in 1907 and the constant worry over the San José scale, *A. perniciosus,* were probably the final pressures toward the appointment of Dr. Robert Matheson in 1912.

The Outbreak of the Brown-tail Moth

Probably no one insect did more to precipitate a sudden expansion in entomological facilities than the outbreak of the brown-tail moth in 1907. A close rival as a sensation was the introduction soon after of the greatly feared San José Scale. Neither insect actually lived up to the virulence expected of it.

The rapid expansion of staff and facilities induced by the brown-tail moth outbreak no doubt simply speeded up an inevitable process of growth. At least, like the Colorado potato beetle before it, the brown-tail moth infestations had long-lasting influences. The difference this time lay in the rapid response by the Office of the Secretary for Agriculture which immediately placed crews of men in the field.

The suggested date of the introduction of the moth is 1905, but the nests were first discovered by Mr. Perry Foot in his orchard in Lakeville, Kings Co. in 1907. As stated above government response was speedy. Under the direction of Prof. Smith, and headed in the field by H.G. Payne and G.H. Vroom, the survey groups showed that the infestations extended from Yarmouth County to Kings County. In the next few years the outbreak expanded even more widely and a concerted attempt at eradication was made. There was winter scouting with the destruction of nests; fruit growers were encouraged to spray; and government-operated sprayers were placed in the field with crews under the direction of Payne and Vroom. Seemingly the actual ravages of the brown-tail moth were never as serious as expected.

Nevertheless, because of it, the Federal Government took steps important to the future of entomology in Nova Scotia in 1910. The outbreak was declared a national problem and a crew of five men, under the direction of Mr. G.E. Sanders was appointed to cooperate with the provincial men. In addition to scouting, these appointees were charged with making a study of the brown-tail moth with a view to its eradication.

The discovery that the population was maintained at a low density in Europe by natural means had induced experts in the United States to introduce about thirty different species of parasites and predators into northern New England. Under an international agreement and with the authority of L. S. McLaine in Ottawa, some parasites and predators were introduced into New Brunswick and Nova Scotia between 1912 and 1915. These were the climbing around beetle *C. sycophanta,* and tachinid *Comsilura concinnata* Mg., the braconid *Apanteles laecteicolor* Vier., and the fungus *Entomophthora aulicae* (Reich.).

The period of high densities was short. Reports indicate that by 1916 the brown-tail moth was again becoming of minor importance. Gilliat (1920), in a review of the outbreak considered that four factors, viz. the inspections with the destruction of winter nests, climatic conditions, spraying, and the introduction of natural enemies had all contributed to the reduction. None of these factors can be weighed at this late date.

The Office of the Provincial Entomologist

The appointment of Dr. Matheson in 1912 as Provincial Entomologist made him the first in Canada to hold such an office. He and his successors also served as Professors of Zoology at the Nova Scotia Agricultural College in Truro.

During Matheson's one-year tenure of office the San José scale finally arrived in Nova Scotia. The outbreak was discovered by Mr. G.E. Sanders on a planting of young apple trees in Aylesford, Kings County. Although the pest never became the disaster expected of it, the initial fear upon its discovery generated an intensive eradication campaign, including the fumigation of nursery stock. The insect had already made the Department of Agriculture in Ottawa more conscious than ever of the need for trained entomologists and for consistent efforts to combat insect pests. The passage of the San José Act in Ottawa in 1899 had been a measure of the virulence of this pest elsewhere in Canada. The prohibitions were lifted in 1901. New legislation (see Hewitt 1911) incorporating a broader application of inspection and prohibitions was embodied in the "Act to Prevent the Introduction or Spreading of Insect Pests or Diseases Destructive to Vegetation" in 1910. Nova Scotia followed suit in 1911 with its "Injurious Insect Pest Act".

Dr. Cuming (1912) Principal of the Agricultural College said in his report, "We regret to state that during 1912 the presence of an even more insidious pest than the Brown-tail moth has been discovered viz., the San José scale. As soon as the discovery was made scouts were put into the field and every effort made to discover the boundaries of the pest and to destroy infested trees".

Some of the men in the following list of "scouts" are of interest as they later became prominent in entomology in this province. They were: H.R. Brown, S.H. Payne, F.C. Gilliat, C.A. Crocker, Guy Denson, A. Kelsall, Allan Dustan and C. Shipton. Under Matheson's leadership and in cooperation with G.E. Sanders' crew a vigorous campaign of inspection, quarantine measures, the arranging of fumigation of nursery stock, and the burning of infested trees was initiated. Before the campaign was completed Dr. Matheson resigned.

His resignation in 1913 brought a very dynamic and energetic personality, Dr. W.H. Brittain, to Nova Scotia as Provincial Entomologist and Professor of Zoology. His first big job was to carry on the San José scale eradication campaign. Severe as

this scale was, it was less catastrophic than had been feared. The first outbreak was cleared up with an appreciable effort, as have several small localized outbreaks since then.

The majority of Brittain's efforts were divided between his teaching duties, his research on morphology, taxonomic work, and investigations on the biology of pests. He also compiled a great deal of information into bulletins for farmers' use. Last, but not least, he carried on extensive plot work in orchards with the objective of finding safe and effective insecticide-fungicide combinations for insect and disease control.

The Experimental Station and the Entomology Laboratories

For some years prior to 1910 the Nova Scotia Fruit Growers' Association, along with various other groups and interested persons, had been pressing to have a fruit research station established in the Annapolis Valley. The wishes of these people came to fruition in that year. The Provincial Legislature purchased the Sharp farm on the outskirts of Kentville and turned it over to the Federal Government as a base for the station. Mr. J.W. Crowe was appointed temporary superintendent. He turned the job over a year later to Dr. W. Saxby Blair, who developed a fine research station. Although entomology was included in the terms of reference, no facilities were provided at the station for many years. A few years later a small laboratory was erected on the Acadia University campus by the Nova Scotia Government for the use of the Provincial Entomologist. The first entomology at the station came when the provincial extension service acquired rooms there about 1935.

The brown-tail moth eradication campaign was at its height when the Federal Government erected a small laboratory in Bridgetown in 1911. The objectives of its crew were the careful study of the brown-tail moth, investigations on means of controlling its abundance, and the study of other insects on field and orchard crops. This building was abandoned in 1915 when the staff was moved to larger quarters in Annapolis Royal. Research in entomology, thereafter, was directed mainly at the comparison of a great many combinations of insecticides and fungicides and, particularly, at exploring all possible sources for new poisons. A sustained effort was also put into the study of the life histories of many pests. In 1915, also, the Provincial Government erected a log cabin at Smith's Cove in Annapolis County. The Annapolis Royal Laboratory was closed in 1951 and the staff and facilities moved to new quarters in the Science Service Building in Kentville. The latter was incorporated, in part, into the new main building of the Canada Agriculture Research Center opened in 1981.

The Anomaly of the Apple Maggot as a Pest

The purpose of the Provincial Laboratory at Smith's Cove was to provide facilities for a study of the apple maggot, *Rhagoletis pomonella* Walsh. Brittain and Good (1917) did much of their work on the apple maggot there. The interesting anomaly of this pest is that it has attracted and received far more attention than have many pests which in some way damage the tree, foliage, or fruit to a greater extent. It has rarely been the cause of appreciable damage to fruit in commercial orchards, but has resulted in growers being unable to ship infested fruit to certain markets. For the latter reason it has been the cause of some economic losses to growers.

The hypothesis that the apple maggot is a native insect that transferred from the hawthorn (*Crataegus* spp.) to apple suggests that it was here before the apple tree was introduced. The first official identification of the apple maggot adult was made by Matheson (Brittain 1913) who collected specimens in Digby County. That date is, of course, no indication of how long the maggot has been attacking apples in

Nova Scotia. The introduction of apple trees in the early 1600's (Hutten 1981) suggests the earliest, though unlikely, time of transfer to apples as a new host. Hutten's account of apple trees coming in with the New England Loyalists and Planters suggested about 1760 as the earliest reasonable date, if such a transfer did take place. It is not known when apple maggot damage was first recognized as important. Although it seems probable that it was long ago, it is interesting that there is no reference to apple maggot in the *Annual Report of the Nova Scotia Fruit Growers' Association* until after 1900.

If, as assumed, the apple maggot has attacked apples for a long time, its failure to become abundant in commercial orchards was due to the use of arsenicals. These were fairly generally employed before the beginning of the 20th century and very extensively after that. By the 1920's and after, when all commercial spraying included arsenic, the maggot was scarce in most commercial orchards though often abundant outside of the main growing areas.

Attitudes changed greatly after 1925 when Dr. Arthur Gibson, Dominion Entomologist, explained the probability of a British embargo on apples from any area if live maggots were to be found in shipped fruit (Leonard 1933). The following account of the steps taken to avert a disaster in Nova Scotia is based on communication with Mr. Alex Buchanan, Chief Inspector of the Apple Maggot Control Board for thirty-one years, and on the paper by Leonard (1933). The apple maggot achieved lasting notoriety in 1926 when a survey showed the pest to be present, at least in small numbers, throughout the Annapolis Valley. As the English tolerance was zero it was a startling find. Leonard stated, "That same year, 1926, the Provincial Government passed an order-in-council prohibiting the export of apples infested with apple maggot. Under this authority Federal Fruit Inspectors were authorized to hold up infested fruit. There were, however, small provisions for enforcement at first. A comprehensive survey in 1930, with the finding that infestations were extensive, led to the setting up of a largely non-government board called the Advisory Apple Maggot Control Board. Inspectors were appointed to facilitate enforcement of legislation. A further change was made in 1932 when a board of growers called the Nova Scotia Apple Maggot Control Board succeeded the Advisory Board.

It is difficult to give a summary of the control of this unique pest, not normally excessively destructive in sprayed orchards, without minimizing the problems entailed in guaranteeing freedom from it in exported apples. Nevertheless that standard was achieved by an intensive effort. Before the outbreak of World War II about 50 inspectors averaged over 5000 visits per year, many within towns where neglected apple trees were a special problem.

The British market, lost due to the war and never fully recovered, caused a number of changes in the approach to the apple maggot problem. The most obvious ones were the increase in the numbers of neglected trees and a more indifferent attitude on the part of farmers. In the period 1950-1960 the numbers of yearly visits dropped to about 1500 and in the 1970's to around 400. Of late years there have been, at most, 10 to 15 inspectors who respond only when an application for inspection is made.

The arsenicals, which have at all times given reliable control, have not been used greatly since 1970 for several reasons. Prominent among them were the difficulties of enforcement, the numbers of wild and neglected trees, an abundance of hawthorn bushes, and changes in the spray program to suit the control of other pests. At the present time sticky traps are used to indicate levels of fly abundance which, in turn, tell the grower if an application of an organophosphate is required.

The Entomological Society of Nova Scotia and the Acadian Entomological Society

The Acadian Entomological Society, as presently constituted, began in 1915 as the Entomological Society of Nova Scotia, changing to the Acadian Entomological Society in 1921. Unfortunately, there is no known file of correspondence in which to find plans for its inception. Whatever the plans, the prerequisites for organizing had been building for a number of years. There had been an increase in the number of entomologists because of the brown-tail moth and San José scale; the Federal Government had begun to take an indirect part, as in the appointment of Sanders' crew; there was a body of interested taxonomists and collectors; and there was increased spraying of orchards with consequent pressure from growers for information.

The organization under its first name, and later under its second, published its proceedings each year from 1915 until the society became defunct in 1924. The closest we can come to a statement of objectives is contained in the remarks of the Honorary President, Dr. A.H. McKay, in 1915. He used an old concept which is still applicable, viz. "The great war of the future will be between man and the insects. Man is greater; but the insects propagate more rapidly. Were the insects not divided against themselves in six years the human race would be starved into extinction . . . . It is knowledge gives us power. The greatest forces in the world are often invisibly small; so long as we do not know them, and how and when they act, we are helpless as inert matter" (McKay 1915).

Characteristically, Dr. Brittain was the main force behind the new society. He made more contributions to the proceedings than any other individual (Table I) and most of them were above average in quality.

Table I Sources of papers published by the Entomological Society of Nova Scotia and the Acadian Entomological Society.

Year	No. papers submitted all sources	No. papers submitted by non-resident entomologists	No. papers submitted by Brittain
Proceedings of the Nova Scotia Entomological Society			
1915	14	0	2
1916	13	0	5
1917	16	3	3
1918	13	1	4
1919	8	1	3
1920	10	3	2
Proceedings of the Acadian Entomological Society			
1921	8	6	2
1922	13	5	3
1923	6	3	1
1924	9	3	1
	110	25	26

Total Pages = 893
Total Pages in Brittain's Papers = 294

Unfortunately, the membership remained small (e.g. in 1921 there were 16 members from Nova Scotia, 11 from New Brunswick and 2 from outside the Mari-

times) which is obviously the reason the society was unable to find sufficient numbers of high quality papers. The failure of the Acadian Entomological Society to survive did not mean there had been any slackening in progress in the entomological sciences.

Coincident with the outbreak of war in 1939, events only remotely related to those just outlined had the effect of reviving the Acadian Entomological Society. The bringing back to life of the 15-year-dead society was not a miracle of resurrection. When a meeting was arranged in Orono, Maine, in 1939 between A.D. Pickett, C.W. Maxwell and Maynard Harrison (the latter two from Fredericton) and F. Lathrop, reorganization was not a part of the plan. The meeting was simply to discuss controls for an outbreak of the blueberry maggot, *Rhagoletis mendax* Curran, in Yarmouth County, Nova Scotia, and other blueberry problems. In the light of the present strength of the Acadian Entomological Society there can be little doubt that there was a latent need for a reorganization of the Society.

When Dr.Lathrop drew attention to similarities in the environments of Maine and the Maritime provinces the discussion led to an invitation to have a larger group meet in Orono during the following year. The suggestion was enthusiastically received and acted upon. In January of 1940, Pickett, Maxwell, Dr. J. McBain Cameron, Provincial Entomologist of Nova Scotia, and Mrs. Jean Adams, along with a delegation of forest entomologists from Fredericton, met in Orono with entomologists from Maine. That informal exchange of ideas was such a success a decision was made to meet again in Fredericton in 1941. The meeting in Fredericton set a repetitive pattern because of its stimulating value; from the first it was evident that much good was to come of these gatherings. The group, thinking of themselves as the Maritime and Maine Entomologists, but without a formalized name, continued to be a valuable unifying medium for entomology in the Atlantic Provinces and Maine.

The concept of forming an officially organized society met with some doubts for a time. For example, a letter written by W.A. Reeks, who was not averse to the idea, expressed doubts that a branch of the Ontario Entomological Society would be formed. The idea stayed very much alive, however, and grew stronger. The first positive step to make the organization official took place on 29 March 1950 when the constitution presented for discussion was adopted. The society was, thereafter, to be the Acadian Entomological Society. It was to affiliate with the Ontario Entomological Society but not be a branch of it. At that time the Ontario society was still the Canadian parent society. Upon the reorganization in 1950 which made the Ontario Entomological Society an affiliate of the new national Entomological Society of Canada, the Acadian Entomological Society affiliated. The by-laws of the latter were altered in 1953 to conform with those of the parent society. A further change in by-laws became necessary in 1957 to have them conform with clauses in the parent society constitution when that society was incorporated in 1955. Mrs. Jean Adams (1965), in her popular write-up of the 50th anniversary of the Acadian Entomological Society, and speaking of both the national body and its affiliate, had this to say: "The second world war had passed . . . . the ranks of professional entomologists in Canada as a whole had begun to swell. Many felt the need for a truly national society to speak for so wide a group . . . . In the Maritime area, what the nature of the affiliation should be was debated at considerable length. The outcome was the revitalization of the Acadian Entomological Society, to include all interested entomologists, in the four Maritime Provinces and Maine."

The proceedings of the society have been issued each year since 1961 in multigraph form as a record for the future. That future looks good because of what the society has done, and promises to do, for entomology in this geographic area.

The Period From 1915 to 1939

As was pointed out the erecting of an entomological laboratory in Annapolis Royal in 1915 with G.E. Sanders in charge had provided facilities for the investigation of orchard problems. The main effort thereafter went into field and laboratory investigations on the development of combination sprays for insect and disease pests. In addition, Mr. F.C. Gilliat devoted the rest of his life to the study of the bionomics of apple insects. Sanders had already been involved, at least as a consultant, in Brittain's orchard experiments when he made what he considered to be a fateful visit in 1915 to the orchard of Mr. G.L. Thompson in South Berwick. There, he was able to verify the suspicion that the heavier use of lime-sulphur was cutting the apple crop drastically, even though it provided excellent finish to the fruit. The fortunate observation probably simply speeded up a study of spray damage to fruit that had become inevitable.

Research on Insecticide-Fungicide Combinations

Beginning in 1916 the major role of the entomologists (after 1924 in cooperation with the Plant Pathology Laboratory in Kentville) at Annapolis Royal was the evaluation of a very large number of insecticides and fungicides and combinations of them. Lead arsenate combined with lime-sulphur, the hitherto common mixture, was found to be more dangerously phytotoxic than when calcium arsenate was used. Alone, lead arsenate was fairly safe and calcium arsenate dangerous. Calcium arsenate was safe in Bordeaux mixture which, by the post-war years, was being used with an excess of lime to make it less toxic to foliage. The spray calendar by 1918 was recommending the higher lime Bordeaux with calcium arsenate (or lead arsenate) in the early and late sprays and lime-sulphur with or without calcium arsenate in the bloom period sprays. A considerable amount of nicotine sulphate was being used then for such pests as aphids and the green apple bug, *Lygocoris communis novascotiensis* (Knight).

When dusting achieved popularity in the period after 1918 the most successful combinations were: elemental sulphur with lead arsenate in the proportions of 90 to 10, Bordeaux mixture with calcium arsenate, and nicotine sulphate in Bordeaux or with hydrated lime. Unfortunately, despite the high hopes generated for dusting, it failed to meet expectations. After 1924, growers began to abandon the practice and revert to spraying. Kelsall (1939) says of the decline of dusting, "This period of seven or eight years during which dusts were so extensively used was terminated by two factors. Extreme outbreaks of the eye-spotted budmoth, *Spilonota ocellana* D. and S. occurred in the years between 1924 and 1927, causing great damage to the crops. These could not be controlled by any known dusting method. At the same time, in large numbers of orchards, the European red mite, *Paratetranychus pilosus* C. and F. [now *Panonychus ulmi* (Koch)] became a serious pest and this, likewise, was not amenable to dust treatment. These two factors coupled with the development of improved high-powered spray outfits led to a decline of the dust method of control and to the revival of the spray system".

The addition of the European red mite to the list of major pests complicated the spray program still further. Mineral oils, later with such additives as the "dinitros", provided temporary relief for one to three years. Often the concentration of the oil was increased to check the abundance of the oystershell scale and other pests. A still further cause of concern following the outbreak of the budmoth was a marked increase in the gray banded leaf roller, *Eulia mariana* Fern.

Arsenicals and the Bee Populations

Growers had long been aware of the scarcity of hive bees and the identity of the

cause, though suspected, was not established. When Brittain (1933) began his investigations on bees in 1928 it was to ascertain the effects of arsenicals on pollination through destruction of the bee population. It soon broadened into an outstanding piece of research on all factors affecting pollination of apples in the Annapolis Valley. It was already known to be impossible for the bee-keeping industry to exist in the apple producing area. Also, although it was recognized even then that hive bees can be the main agent in pollination, they were normally a negligable factor in the sprayed areas. Brittain's research soon showed that, with the avoidance of arsenicals in the bloom period, 1 hive of bees per acre gave effective pollination. Occasionally, 1 hive might be sufficient for as much as 3 acres. In general, however, the finding was largely academic as there was no large supply of bees. Most apiaries had been wiped out or had moved from the Valley during the years in which dusting was popular. Following that period the high-powered sprayers, with greater drift of materials, continued to inhibit beekeeping. Although sulphur dust caused trouble in hives, the lead and calcium arsenates were the main cause of death among honey bees. While most of the poisoning took place in the bloom period of apples, that was not the only period of danger. The drift of sprays to wild flowers, such as the dandelions, was also a common cause of poisoning.

Of the other Hymenoptera, the bumblebees were less deterred by weather than either the hive bees or the solitary bees. Brittain found it impossible to determine in the field if the minor importance of bumblebees in orchards was a result of poisoning. Only 5 species of them, all in the genus *Bremus*, were recorded during the bloom period in the years the research project was in effect.

The solitary bees were far more important than any other insect in arsenic treated orchards. This included, in particular, the hive bees because of their susceptibility to arsenic poisons. The 5 year study of solitary bees revealed 12 species of *Halticus* and 10 species of *Andrena* on apple blossoms. Of these, *Halticus smilacinae* Robt. was the most important pollinator because it far outnumbered all other bees. As with the bumblebees, evidence of poisoning was, by its very nature, impossible to obtain in the field.

Dead broods of wild or solitary bees were seldom found, and dead adults too rarely to determine if they had died of poisoning. Brittain (1933) sums up his observations on the poisoning of wild bees this way: "The fact that such a large proportion of the pellets, collected at random, contained measurable amounts of arsenic would lead one to suppose that poisoning among wild bees should be common; but if so, it is difficult to demonstrate, and over the period studied we have not been able to detect any diminution in the effective population traceable with certainty to this cause". Also, according to his report, solitary bees were found nesting in great numbers in areas where most severe losses in hive bees took place.

Poisoning of all kinds of bees by materials other than arsenicals has never ceased to be a danger of serious concern to entomologists.

The Period of the use of Precipitated Lime-Sulphur and Flotation Sulphurs

Even as the studies by Brittain were being pursued in the late 1920's, alternatives to the lime-sulphur and calcium arsenate mixture, normally used in the bloom period, were being sought by entomologists at Annapolis Royal and by plant pathologists at Kentville. As early as 1924, lime-sulphur precipitated with aluminum sulphate was showing value as a safe material to use on apple foliage. Unfortunately, it left much to be desired as a fungicide and its use was short-lived. Kelsall's (1939) first attempts to increase the fungicidal value of lime-sulphur by precipitating it with iron sulphate were not notably successful. But, upon increasing the calcium arsenate from 3 lb to 5 lb per 100 gallons the mixture proved

to have the desired qualities. Its use gave satisfactory control of apple scab and did not mar the skin of the fruit. Many growers began to use the mixture in the bloom period, and some in all sprays.

The testing of a wide range of insecticides, both in combination with fungicides, and alone became the main effort of entomologists during the 1930's. There was, however, no fundamental change in the concept of using sulphur-based fungicides. Nor did there appear to have been thought given to any other means of controlling arthropod pests than by insecticides.

Among the new sulphur fungicides given a high rating in the early 1940's was flotation sulphur, a by-product of the coke industry. It was elemental sulphur in very fine form precipitated by hydrogen sulphide in the production of artificial illuminating gas. In the period mentioned it largely supplanted the lime-sulphur-iron sulphate mixture. It provided excellent control of apple scab, and gave the fruit a beautiful finish. Its shortcomings will be examined in considerable detail later.

Investigations on the Life Histories of Pests

It was imperative, in developing spray programs after 1915, that there be knowledge of the cause of each kind of damage and of the life histories of the casual agents. Studies on the bionomics of the pest species became, therefore, an important correlative part of the control investigations. Unfortunately, although information on the natural enemies was gathered as well, it was considered to be of relatively minor importance. Nevertheless, in spite of the shortcomings a valuable body of biological information was built up.

Two of Gilliat's papers in particular, both published in 1935, proved in time to be very significant contributions. One (Gilliat 1935a) was on the biology of the European red mite, *P. ulmi* and the other on its predators (Gilliat 1935b). This information was fundamental to later studies (to be described) on the evolution of spray programs that made great use of natural enemies. Gilliat had said, significantly, "As a summary, the many predators must be considered in the light of a common enemy of the European red mite, a natural balance being established under normal environments. Where there is interference with the factors of natural control there follows a rise in the numbers of pests which end in destructive outbreaks". His personally expressed, but unpublished view, that spray policies should consider natural enemies was not acted upon. The time was not then ripe as entomologists were still continuing the search for the ideal combination of spray materials for all pests. The general view was that the destruction of natural enemies was not important if all their food animals were dead. That philosophy remained popular long after 1940 among many entomologists, with a growing number of exceptions. Before the 1940's the few who decried the ill-advised use of spray materials had been voices crying in the wilderness of misconceptions about nature.

The Background of Integrated Control

The day of a fundamental change in concepts of control of orchard insects was not far away when war broke out in 1939. The initiative and basis for change was an economically depressed apple industry which had lost the British market.

The reshuffling of personnel in 1939 that had seen Kelsall become superintendent of the Kentville Experimental Station had brought A.D. Pickett to the Annapolis Royal Laboratory. The latter, as Provincial Entomologist since 1928, following the resignation of W.H. Brittain, had promoted and directed an extensive spray circle service for farmers. The service was designed to help growers by

providing technical information quickly. Special problems were brought to the best specialists. Such a liaison was highly necessary at the time as the acreage was large and the problems many. These experiences had placed Pickett in an ideal position to observe that the recommendations had weaknesses, although no one knew why at the time. Increased spraying only seemed to bring about more problems.

By the time war broke out in 1939 the control of apple pests had become complicated and expensive. The costs were tolerable only if there was both a large market and prices sufficient to cover costs. The so-called "best" growers were applying a combination of pesticides in a series of applications lasting late into the summer. By 1940 growers were including more and more flotation sulphur, sometimes in all applications. Beginning with dormant oils, the schedule often ended the season with four or more applications of lead arsenate and final sprays of fixed nicotine or cryolite for the codling moth. If high quality fruit is considered to be free of blemishes, then Nova Scotia was producing high quality apples. Grading standards based on this criterion, deemed so desirable by the public, were stringent. Skin quality, no doubt, will always set the standard of acceptable quality, and thus be the determinant of spray policy.

By 1939, the oystershell scale had moved to top position as a destructive pest. If growers failed to check its increase with dormant oil every two to three years the life of whole blocks of orchard was threatened. Yet, Brittain (1913) had told fruit growers that this insect had many natural enemies and that it was easy to understand why it had never been more serious.

The European red mite, too, had reached a level where, at a distance, orchards often appeared red because of huge numbers of winter eggs. Lower concentrations of the same dormant oil used for the oystershell scale were recommended.

The eye-spotted budmoth was also a major pest and was controlled with a summer application of nicotine sulphate. There were several other lepidopterous pests but the codling moth had achieved top place. In 1941, for example, it was demanding more and more attention, particularly among those making the heaviest applications of spray; yet Sanders (1915) had dismissed the pest with these words: "Owing to its comparative scarcity in Nova Scotian orchards the codling moth has received little attention as yet in this province. It is very rare to find even an unsprayed orchard which gives over five percent wormy apples . . . . "

There were many other pests but the above four ranked highest in importance at the time. To summarize, it was anomalous that when the economic crisis of 1940 hit, the more intensive the spraying the more intense were the problems from insects. After 1940 the real crisis was survival of the apple industry. The only compromise was to produce at minimal costs and maintain the health of the orchard until the return of better times. All reduced their spraying and some ceased entirely. The situation provided a whole new environment demanding a more economical approach to pest control. It forced entomologists to modify spray recommendations and A.D. Pickett put the machinery into gear as the new officer-in-charge.

Warnings against the dangers of interfering with natural processes through the injudicious use of sprays had been voiced for years past by prominent entomologists on this continent. Unfortunately, circumstances had left these warnings unheeded. Suddenly they were very apropos to the conditions caused by the war. Pickett's background of 10 years' experience in chemical pest control had made him aware that spray practices contained some inexplicable contradictions; just what they might be was not at all clear to anyone. Pickett, with typical determination, persuaded headquarters in Ottawa that the adverse effects of sprays should be investigated carefully. Thereafter, the energy of the staff was devoted to

unravelling the many intricacies determining the interactions of natural enemies with pests in a sprayed environment. The new line of approach at first exploited the misfortunes of the apple growers to a marked extent. Strange situations with respect to natural control began to turn up in blocks where spraying had been reduced or abandoned.

Unexpected decreases in pests in some of these in 1943 and after, provided conditions for an early understanding of the importance of natural controls. For example, in one such orchard, scalicide tests proved worthless because the scales in the check plot all died of natural causes. In other neglected orchards there was no large resurgence in pests.

Integrated and Modified Control in the Earlier Years

Research soon showed that a parasite, *Aphytis mytelaspidis* (LeB.), and a predacious mite, *Hemisarcoptes malus* (Shimer), normally held the scales in check. The influence of spray on them was an early project in the new approach. Sulphur fungicides were found to set the stage for an outbreak of scales.While lime-sulphur fungicide had some toxicity to scales it was not sufficient to hold them completely in check once the natural enemies were killed. Flotation sulphur, on the other hand, was particularly disastrous. It had no toxicity to scales but it was extremely harmful to the natural enemies. A new fungicide, first under test in 1943, might have failed to find commercial use but for its role in solving the scale problem. Ferbam (ferric dimethyl dithio-carbamate) was by no means ideal for apple scab suppression, but it was harmless both to scales and their natural enemies. The substitution of this fungicide for sulphur in commercial orchards allowed natural enemies to clean up the scale populations, usually in one year. This phenomenal success was, perhaps, equally important in its service as an object lesson on the adverse effects of sprays. It was not soon forgotten by the farm population.

Because Bordeaux mixture and the fixed coppers were also innocuous they, too, were of value for some years in maintaining a low density of oystershell scale. The organic fungicides introduced after 1953 also had this favourable property.

The European red mite, *P. ulmi*, was the second important pest to respond positively to changes to sprays with minimal effects on predators. Studies on mites and their predators, initiated in 1944, increased the list of known predators discussed by Gilliat (1935b), while also evaluating their relative importance. After 1944, a great many poisons and combinations were evaluated for their effects on predators and parasites. It will be pointed out in context that the general predators attacking mites also attack a wide range of other species. As with the oystershell scale the prime villain at first was the sulphurs. Ferbam was detrimental to a few of the predacious species but not to a disastrous extent. It did not prove difficult to find spray materials to allow the natural control of mites to function normally, provided mites were the only important problem. As expected, mites were seldom the only major pest problem in orchards.

The codling moth and the eye-spotted budmoth, both simultaneously under investigation with scales and mites did not yield to modifications in the spray program so easily or quickly. Nevertheless it was observed that the same general predators were a valued addition to the parasite fauna attacking Lepidoptera. Even if the subtle benefits from predators were not as readily discernable, a policy of non-interference with them paid dividends in the general control of all pests.

Intensive research on the interrelations of the predacious species with all other insects and mites began to provide a better picture of the effects of predators on prey and vice versa. Information on the overall effects of general predators on the arthropod populations in and near orchards began to suggest an explanation of how environmental factors worked to supply orchards with predators. Firstly, all

the important predacious species living on apple trees have been observed on vegetation other than apple trees; broad leaf trees in the vicinity of orchards seem to be particularly important. Secondly, it is supposed that when drift of toxic sprays upsets the balance in the nearby wooded areas, it thus provides conditions, when there is no further toxic drift, for a build-up of predators. These disperse into orchards in search of food. The vegetation surrounding orchards, therefore, is a reservoir which resupplies orchards with predators when the spray program is corrected. The third supposition, which is supported by many observations, is that general predators feeding on a complex of prey tend to feed on the kind of prey most frequently encountered. This last effect, though highly probable, is too complex to unravel in the field. It was, however, demonstrated that the predacious fauna can be of great benefit when detrimental materials are avoided. The principles outlined above probably apply to parasites as well, but it is not clear how surrounding vegetation may affect parasitism.

Among the many papers published on the ecology of insects in Nova Scotia a number were devoted to short and to long term effects of chemicals on the orchard fauna. These are considered in a series of papers under the general title of, "The Influence of Spray Programs on the Fauna of Apple trees in Nova Scotia". The first by Pickett, Patterson, Stultz and Lord (1946) was subtitled, "I. An Appraisal of the Problem and a Method of Approach." There were also many other papers not included in this series.

DDT and the Integrated Control Program, 1945 - 1953

The program evolving for a time after 1945 relied heavily on natural enemies, partly because many growers had little choice. The expression "Modified Control Program", perhaps, then expressed procedures more aptly than the later term "Integrated Control Program" which, in time, became rather sophisticated. One pest, in particular, the codling moth, began to present difficulties by not responding sufficiently to the principles of the "Modified Spray Program". In the late 1940's most growers struggling with a codling moth problem were using four cover sprays of lead arsenate in the summer and ending the season with a spray of fixed nicotine or cryolite. These were expensive but not, in themselves, highly toxic to predators.

Grower pressure for cheaper and more effective control measures was the main reason for their acceptance of DDT despite warnings by entomologists in Nova Scotia and other areas as to its disastrous effects on natural enemies. Almost simultaneously with the acceptance of natural controls in Nova Scotia a divergence of opinion arose because of DDT. The first sample of DDT reached the Annapolis Royal Laboratory in the spring of 1944. Its reputation as a remarkably toxic insecticide was soon verified. It had some use in commercial orchards very soon but, for a short time, a majority of growers continued to favor the idea of protecting natural enemies. Those growers chose to continue with the lead arsenate program rather than suffer the red mite and other problems that the use of DDT and a miticide entailed. Farmers who used DDT for the codling moth got the expected clean-up of the pest and the expected side effects.

By 1953 the high cost of insecticides, combined with too much confidence in predators, and lack of knowledge of their own fauna, led too many growers to omit poisons. Unfortunately, they met with disappointment. Next year, despite both the generally high level of predator populations, and weather unfavorable to the codling moth, there was a swing to DDT, even among those with an adequate population of predators. The entire integrated control program was threatened.

At about that time the revelation of the special qualities of the poison ryania for the control of the codling moth gave growers renewed confidence integrated control. This poison is the ground-up wood of *Ryania speciosa* Vahl., a plant native to

Trinidad. While the producing company was still testing it Dr. D.W. Clancy of West Virginia tested ryania against the codling moth in his attempt to initiate an integrated control program for his area. He found it was not only highly toxic to the codling moth, but had only rather mild adverse effects on the predators. Although expensive, fewer applications were required and it was selective. It was, therefore, economically feasible to use in an integrated control program. Dr. Clancy, in correspondence with A. D. Pickett, suggested ryania as a promising material for testing in Nova Scotia. Accordingly, in 1952, Patterson and MacLellan (1954) began testing it.

After two years of experimentation and observation on its effects on the predator fauna it was found to be even more suitable for Nova Scotia conditions than it had been in West Virginia. It fitted the criteria of a selective insecticide so well it was included in the 1955 spray guide. For almost ten years it continued to do the job and thus lengthened that form of integrated control. A comment by Pickett and Patterson (1959) is revealing. They said, "It is not possible to locate orchards heavily infested with codling moth for testing insecticides."

The ultimate failure of ryania had its origin in the control of the winter moth, *Operophtera brumata* (L.), which had arisen, it appears, from the discontinuance of the pre- and post bloom arsenicals. Ryania had little use after 1970.

The Winter Moth and Cankerworm after 1950

A new and combined problem from the cankerworm and the wintermoth crept in slowly and rather subtly. The cankerworm had been a problem even before Smith (1885) discussed it. In the intervening years until 1940 it was a pest of varying seriousness, depending upon spray policies and parasitism. The cankerworm showed signs of revival just before 1950 as the arsenicals fell into disuse because of DDT and ryania. The 1949 insect forecast simply noted that it was causing damage to shade trees in the towns in the Annapolis Valley. In a few years it merited control measures in some orchards. Still further increases by the mid 1950's led to the recommending of a single pre-blossom application of DDT at a very low dosage (2 oz. per 100 gal.). At that concentration, carefully timed, its use was consistent with the natural control program. It was assumed that sufficient numbers of the predators could escape, particularly the later emerging species.

Initially the winter moth was confused with the cankerworm as both cause damage at the same time. Because the winter moth was more difficult to control, the DDT treatment was increased to a pre- and a post bloom application and azinphos methyl was offered as an alternative. The winter moth is a relatively new imported pest of forest and shade trees, and apple trees. The following summary of its history is based on studies by Embree (1965) and by MacPhee (1967). The initial infestation appears to have been in or near Queens County, Nova Scotia, starting about 1930. It spread over Nova Scotia and into parts of New Brunswick. For a time it was confused with the fall cankerworm, *A. pometaria*, and with the spring cankerworm, *Paleacrita vernata* (Peck). By the mid 1950's it had become sufficiently abundant to require separate descriptions in the control recommendations. The materials suggested for both species were the same, however.

Forest entomologists, in their attempt to reduce damage to forest and shade trees imported and liberated five species of parasites in the two provinces. Only two, viz. the tachanid *Cyzena albicans* (Fall.) and the ichneumonid *Agrypon flaveolatum* (Grav.), were recovered. Parasitism proved to be effective in the forests where survival of the trees was the criterion. That standard is insufficient in apple orchards where minimal damage to fruit is imperative and where the chemical approach to control was the only feasible one. The insecticides, however, reduced the effec-

tiveness of the parasites. Also, increased dosages of poisons were required at times that coincided with the emergence of the better predators.

The greatly reduced abundance of the codling moth by the late 1950's has been mentioned but that condition was about to change because of the winter moth. The routine repeated applications, usually at increased dosages, of the organophosphates for the winter moth had an adverse effect on the predator populations. Indirectly, this was a most important, if not the primary, factor in triggering a major outbreak of the codling moth (MacLellan 1969). Because there was insufficient help from predators under these circumstances it became the policy to control the codling moth with materials more widely toxic than ryania. The change marked the beginnings of a new strategy of pest control called Pest Management.

The Beginnings of Pest Management

Events long past have the advantage of perspective in their interpretation; the role played by the older form of integrated control before 1974, is however, too recent for accurate appraisal, and viewpoints vary. The faintly pessimistic one contained in Dr. David Crowe's address to the Fruit Growers' Convention in 1974 has many points of interest as a summary. He told the growers (Crowe 1974): "The contribution of the integrated pest control program to net profit is not well documented. Certainly the cost of pest control was becoming excessive when we started the program 35 years ago. In Nova Scotia we went the biological control route and accepted a fair degree of injury while we learned how to work chemicals into the program without undue loss of natural control. Other areas utilizing the new and powerful chemicals are attempting to work biological controls into their programs. Certainly we saved money and have now developed very satisfactory controls within the integrated program but there are occasionally some losses of quality and total yield. This is true for both types of programs of course. It is likely that the chemicals developed since World War II have, and will, contribute more to net profit than does the integrated control concept *per se*".

That form of integrated control based on exploiting the limited selectivity in available pesticides and the avoidance of broad spectrum ones changed in the late 1960's. Ryania lost popularity, became scarce, and was dropped after 1970. Because of problems from the winter moth and the apple brown bug *Atractotomus mali* (Meyer) growers, as mentioned, seriously disrupted predator populations by using organophosphates. This, according to MacLellan (1979) triggered the codling moth outbreak previously discussed. In the hope of obtaining sufficient reduction in the codling moth population and a return to less generally toxic materials azinphos methyl, at larger dosages, was recommended for a 1-year period. The codling moth was controlled but there was no change back to less drastic poisons.

With exploration and development of all efforts in commercial insecticides directed into a search for pesticides as broadly toxic as possible, there seems little likelihood of selective materials being produced. No one will argue against the inference in Crowe (1974) that making maximum use of natural enemies through the use of selective pesticides holds little promise.

The control of pests at the low level demanded by the fresh fruit trade, without destroying natural enemies, it is true, limits the choice of materials. Yet this is being done to a fair degree through pest management. In this respect it is of considerable benefit to growers that over half the apple crop is sold under the less stringent skin quality demands required by the processing industry. The economic returns of production, whether for the processing or for the fresh fruit trade, are the final determinant of the treatments to be applied.

The monitoring system using sex pheromone for determining whether or not a poison treatment is needed for the codling moth is one of the best in use. These

very successful moth traps show promise of similar developments for other pests. Densities of many, but not all, pests can be monitored at present in a number of ways. With monitoring tools the benefits of using the least widely toxic materials at the lowest practical dosages, carefully timed, and applied only as required, makes the pest management system the main form of integrated control today.

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GROWTH AND PRODUCTION OF THE INTERTIDAL AMPHIPOD *COROPHIUM VOLUTATOR* (PALLAS) IN THE INNER AND OUTER BAY OF FUNDY.

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Populations of *Corophium volutator* were sampled at Avonport, Nova Scotia, in the inner Bay of Fundy and at Musquash Harbour, New Brunswick, in the outer bay. At Avonport an overwintering and a summer generation were present from August to July and June to November, respectively. In contrast, at Musquash there was only a single annual generation that was first observed in early July and persisted until September of the following year. Annual production was estimated as about 22 and 9 g dry weight/m^2 at Avonport and Musquash, respectively. The lower (up to 10°C) water temperatures of the outer bay from May to November may account for much of the difference in life cycle and production between the two locations.

Des populations de *Corophium volutator* (un amphipode intertidal) furent echantillonées a Avonport, Nouvelle-Ecosse, dans la partie interieure de la baie de Fundy et à Musquash Harbour, Nouveau-Brunswick, dans la partie exterieure de la baie. À Avonport, une génération nivernante et une génération d'été étaient présentee d'août à juillet et de juin à novembre, respectivement. Cependent, à Musquash il n'y avait qu'une seule génération annuelle qui a été observeé tout d'abord au début de juillet et qui a persistée jusqu'au mois de Septembre de l'année suivante. La production annuelle a été estimée à 22 g poids sec/m^2 à Avonport et 9 g poids sec/m^2 à Musquash. Une plus faible temperature de l'eau (jusqu'a 10° C), dans la partie exterieure de la baie, des mois de mai à novembre pourrait être grandement responsable de la difference dans le cycle de viè et dans la production entre ces deux localités.

Introduction

The inner reaches of the Bay of Fundy (Fig 1) are characterized by a tidal amplitude of up to 15 m, extensive soft-bottom intertidal flats and water that is highly turbid and relatively warm in summer. Toward the mouth of the bay the tidal amplitude, turbidity and summer water temperatures decrease markedly and the intertidal flats become smaller and less numerous. While the invertebrate fauna of the intertidal flats of the inner bay has been and is being investigated (Moyse 1978), there has been little research on the intertidal flats of the outer Bay of Fundy.

On the E coast of North America the distribution of the tubicolous amphipod *Corophium volutator* (Pallas) is limited to the Bay of Fundy and Gulf of Maine (Shoemaker 1947). In Minas Basin (Fig 1) *C. volutator* is the dominant inhabitant of the intertidal flats (Bousfield & Leim 1959), reaching densities of over 60,000/m^2. This amphipod is the most important prey of a number of species of fish (Gilmurray & Daborn 1981, Imrie & Daborn 1981) and tens of thousands of migratory shorebirds (Hicklin and Smith 1979). Detailed knowledge of the biology of the species is therefore important in understanding the Bay of Fundy ecosystem.

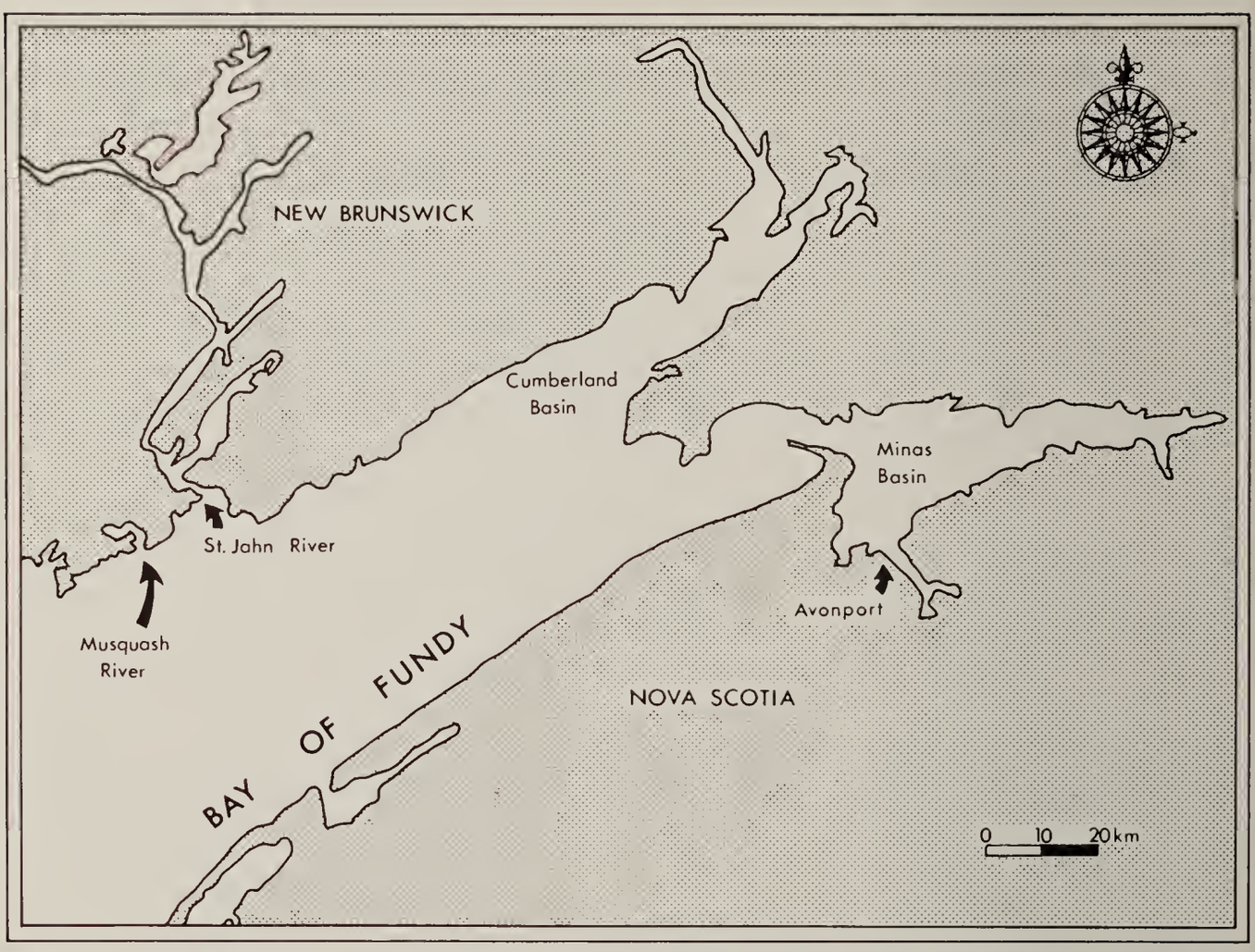

Fig 1. Map of the Bay of Fundy showing location of study sites: Avonport and Musquash.

Study Area

The intertidal flat at Avonport (Fig 1) is up to 1 km wide and is connected to other flats in western Minas Basin. From an upper band of coarse sand the substrate changes abruptly to a soft silt-clay mixture that gradually becomes firmer and sandier out on the flat and finally grades into coarse sand and gravel at low water.

Hepburn Basin is on the SW shore of the Musquash River (Fig 1) approximately 10 km south of the Saint John River. The intertidal flat is a small enclosed bay, roughly circular with a diameter of 800 m. The opening into the bay is about 100 m wide at low tide. The substrate at high tide level is a mixture of bedrock, cobble and saltmarsh. Below this is a similar gradation from soft silt-clay to sand as described for Avonport.

Materials and Methods

Transects were established perpendicular to the shore from high to low water with sampling sites at 150 and 50 m intervals at Avonport and Musquash, respectively. Sampling was done from 1977 to 1979 at Avonport. The procedures used and raw data may be found in Gratto (1979a) for 1977 and 1978 and in Gratto (1979b) for 1979. In 1981 at Musquash 4 substrate samples 10 by 10 cm were taken at each of five stations weekly from May to September.

Samples were sieved in the field through 425 μ mesh, preserved in 4% formalin and returned to the lab where the invertebrates were removed and counted. The length of *C. volutator* specimens from tip of the rostrum to end of the telson was determined to the nearest mm under a binocular microscope.

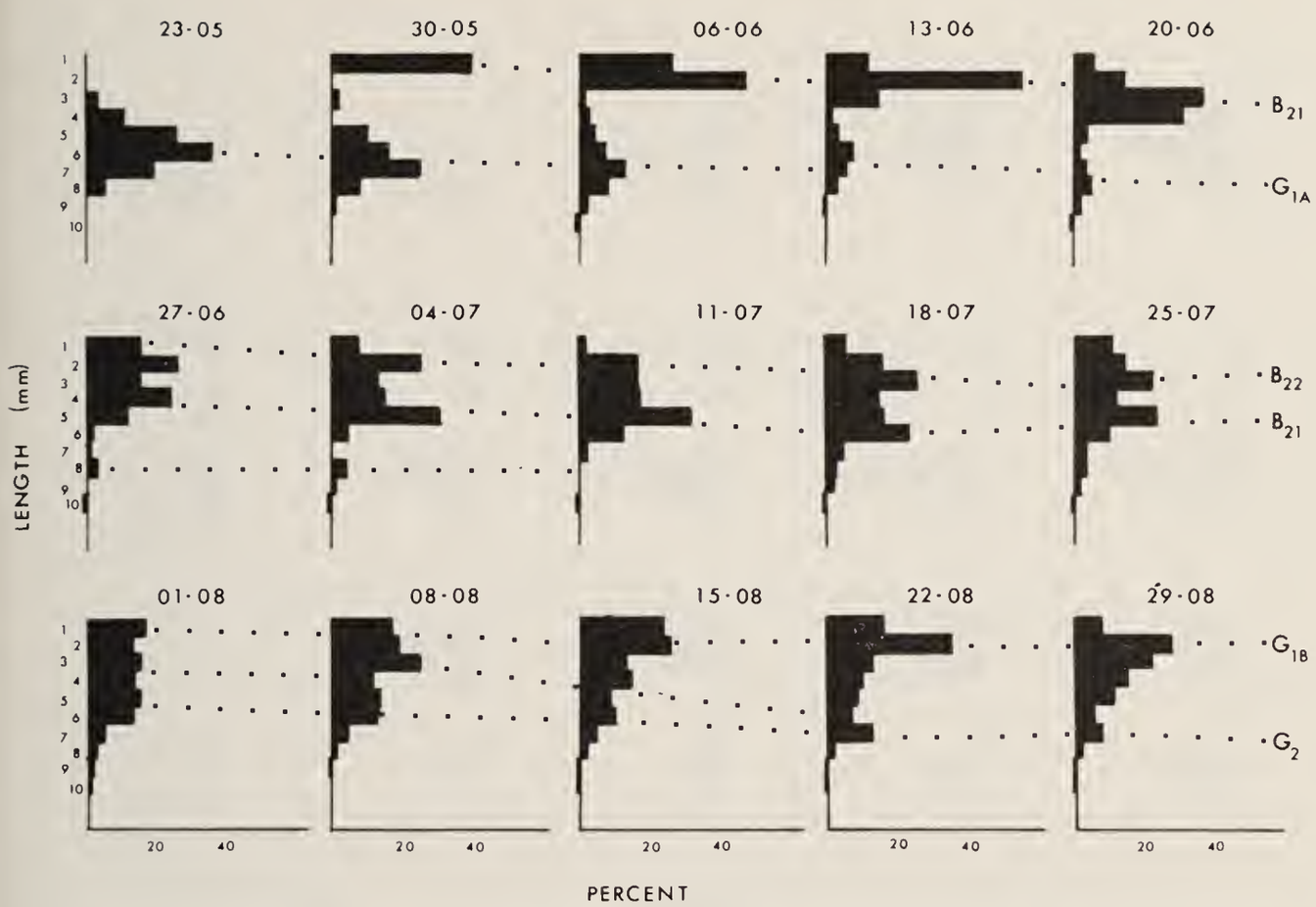

Fig 2. Size distribution of *Corophium volutator* at Avonport in the summer of 1979.

Secondary production was calculated by IBP method 2 (Crisp 1971). Length-weight conversions were made using the equations of Boates and Smith (1979) for specimens from Minas Basin. Mean annual biomass was calculated as the average of total biomass present at monthly intervals over the year. At Musquash the biomass for months not sampled was estimated by linear interpolation between months when data were collected.

Results and Discussion

Size Distribution

In late May and late August, *C. volutator* from Avonport and Musquash had similar size distributions (Figs 2,3) dominated in May by a group that had over-wintered (G_{1A}) and in August by another that will overwinter (G_{1B}). However, size distributions throughout the summer differed considerably. In mid-July the population at Avonport was dominated by 2 broods (B_{22} and B_{21}) in the 2 to 7 mm range while at Musquash the overwintered group of 8 to 10 mm still predominated. The continued presence of the overwintered generation at Musquash until at least September may be the result of slower growth due to colder water temperatures in the outer bay from spring through autumn. From May to December the outer Bay of Fundy is up to 6°C cooler than the inner bay (Tyler 1968; Hills 1980).

The lower water temperatures may also be responsible for there being a single annual generation at Musquash rather than the 2 generations per year observed at Avonport (this study) and elsewhere in the inner Bay of Fundy (Yeo 1978, Boates 1980). In Europe, Watkin (1941) and Fish and Mills (1979) have reported 2 generations per year in the Dovy estuary in Wales. A single yearly generation has been reported only from the more northerly Ythan estuary in Scotland (McLusky 1968) and the inner Baltic (Segerstrale 1940 in McLusky 1968).

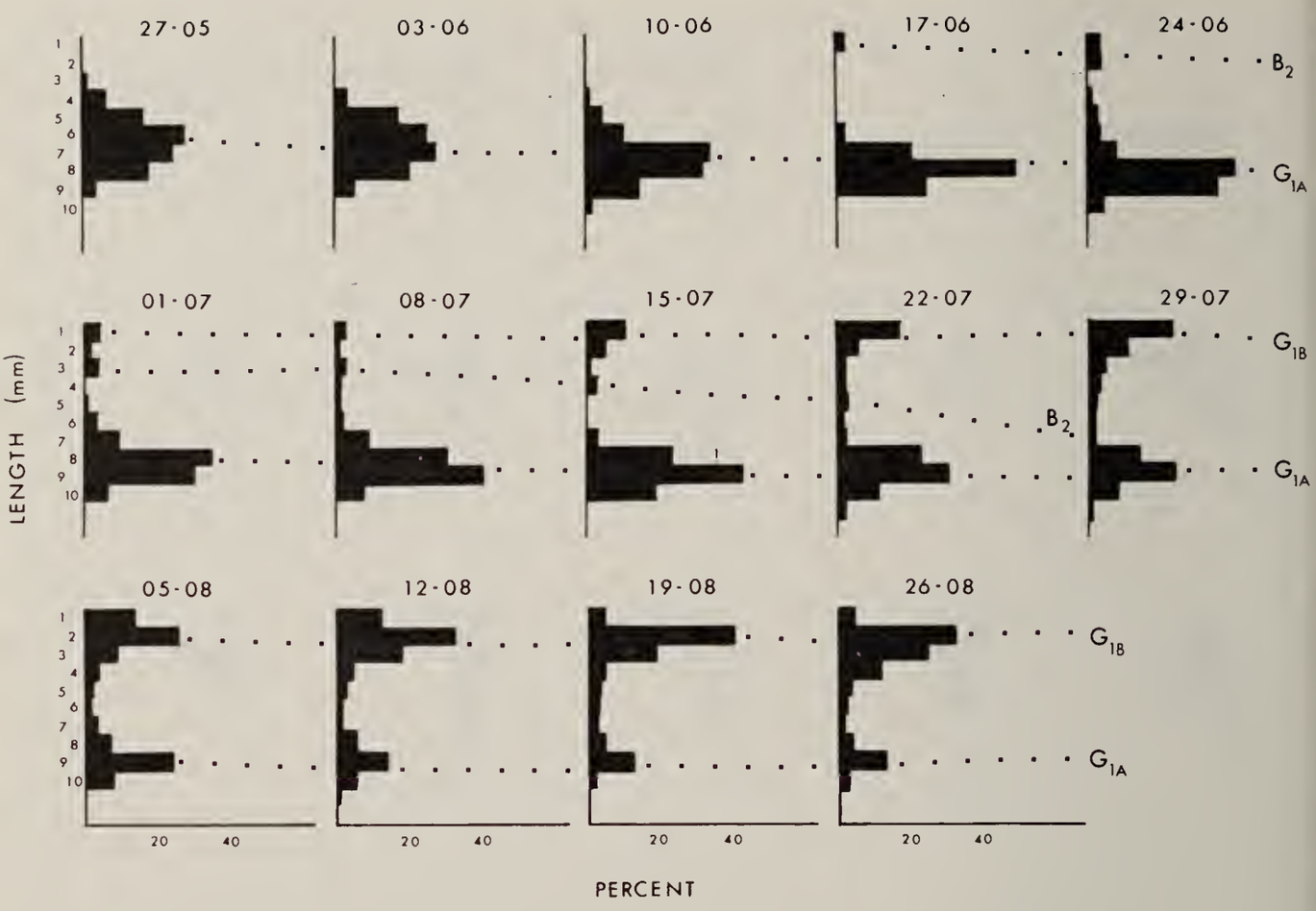

Fig 3. Size distribution of *Corophium volutator* at Musquash in the summer of 1981.

At Avonport 4 broods were released over the summer (Fig 2). The first two (B_{21} and B_{22}) comprising the summer generation (G_2) were produced by the overwintered generation (G_{1A}) in late May and late June. They in turn released the second pair of broods in mid-July and mid-August. These broods initially appeared as an increase in density of 1 and 2 mm *C. volutator* over the previous sampling period and merged to form the overwintering generation (G_{1B}). They grew slowly through the autumn and winter, reproducing the following spring. Brood production appeared to be related to the time of new moons as broods were first observed within a week of the new moon in all 4 months of the sampling period. Fish and Mills (1979) also reported lunar-related reproduction in *C. volutator* with increased crawling activity of males during spring tides immediately followed by a sharp increase in the earliest stage of embryo in the brood pouches of females. Release of juvenile *C. volutator* occurred during the following spring tide period. Although there are no data on increased crawling behavior of males on spring tides at Avonport it probably occurs since, allowing for a development time of 14 days (Fish and Mills 1979), the embryos would have started growth at about the time of full moon each month.

At Musquash only 2 broods were released: one (B_2) in mid-June and the other (G_{1B}) in July and early August (Fig. 3). The first was extremely small and rapidly merged with the overwintered group. Although some individuals may have become reproductive in time to produce juveniles of the second brood their contribution would have been insignificant due to the low numbers involved (less than 5% of the adult population). The second brood overwinters and forms the group of large *C. volutator* that are present throughout the next summer. Individuals not

Table I. Secondary production of *C. volutator* at Avonport. Groups are explained in the text.

Group	Date	Density No./m^2D	Mean density	Mean weight per animal, mg	Change in weight	Biomass g dry weight/m^2	Production
G_{1A}	27/05/77	2500	—	0.620	—	1.550	—
	09/06	1944	2222	0.921	0.301	1.790	0.667
	21/06	3004	2474	0.748	-0.173	2.248	-0.428
	07/07	1140	2074	1.885	1.137	2.150	2.357
	21/07	1164	1152	2.421	0.536	2.819	0.617
G_{21}	09/06	987	493	0.022	0.022	0.022	0.011
	21/06	5855	3421	0.055	0.033	0.322	0.113
	07/07	11391	8623	0.287	0.232	3.274	2.004
	21/07	8706	10049	0.714	0.426	6.215	4.285
	03/08	7667	8186	0.864	0.150	6.624	1.230
G_{22}	07/07	2775	1883	0.033	0.033	0.092	0.080
	21/07	3451	3113	0.065	0.032	0.224	0.100
	03/08	5551	4501	0.099	0.034	0.550	0.153
	17/08	3928	4739	0.680	0.581	2.670	2.753
	16/09	5004	4466	0.930	0.250	4.655	1.119
G_{1B}	17/08	9732	4866	0.054	0.054	0.526	0.263
	16/09	14847	12289	0.119	0.065	1.767	0.799
	12/10	8540	11694	0.385	0.266	3.284	3.105
	10/11	7660	8100	0.450	0.066	3.448	0.532
	07/12	4962	6311	0.410	-0.040	2.035	-0.253
	05/01/78	5251	5106	0.375	-0.035	1.971	-0.177
	02/02	5289	5270	0.433	0.058	2.293	0.306
	06/03	2328	3808	0.493	0.060	1.148	0.227
	30/03	2847	2587	0.594	0.101	1.692	0.262
	27/04	3260	3053	0.666	0.071	2.169	0.217
	24/05	2821	3040	1.232	0.567	3.477	1.724
						$\bar{B}$ = 3.265	P = 22.066
							$P:\bar{B}$ = 6.76

Table II. Secondary production of *C. volutator* at Musquash. Groups are explained in the text.

Group	Date	Density no./m^2	Mean density	Mean weight per animal, mg	Change in weight	Biomass g dry weight/m^2	Production g dry weight/m^2
G_{1A}	27/05/81	4491.7	—	1.12	—	5.031	—
	03/06	3310.5	3901.1	1.41	0.29	4.668	1.131
	10/06	3716.3	3513.4	1.76	0.35	6.541	1.230
	17/06	2387.5	3051.9	2.17	0.41	5.181	1.251
	24/06	3840.0	3113.8	2.51	0.34	9.638	1.059
	01/07	2291.7	3065.9	2.37	-0.14	5.431	-0.429
	08/07	2950.0	2620.8	2.47	0.10	7.286	0.262
	15/07	2907.1	2928.6	2.74	0.27	7.965	0.791
	22/07	2014.3	2460.7	2.77	0.03	5.580	0.074
	29/07	1882.1	1948.2	2.87	0.10	5.402	0.195
	05/08	2162.5	2022.3	2.82	-0.05	6.098	-0.101
	12/08	1493.8	1828.2	3.03	0.21	4.526	0.384
	19/08	1281.2	1387.5	2.82	-0.21	5.564	-0.291
	26/08	1162.5	1221.8	2.90	0.08	3.371	0.098
B_2	17/06	50.0	—	0.01	—	0.000	—
	24/06	240.0	170.0	0.02	0.01	0.005	0.002
	01/07	316.7	278.4	0.04	0.02	0.013	0.006
	08/07	158.3	237.5	0.11	0.07	0.017	0.017
	15/07	135.7	147.0	0.25	0.14	0.034	0.021
	22/07	135.7	135.7	0.46	0.21	0.062	0.028
	29/07	128.6	132.2	0.85	0.39	0.109	0.052
G_{1B}	08/07	125.0	—	0.01	—	0.001	—
	15/07	557.1	341.0	0.02	0.01	0.011	0.003
	22/07	785.7	671.4	0.02	0.00	0.016	0.000
	29/07	1617.9	1201.8	0.03	0.01	0.049	0.012
	05/08	2681.2	2149.6	0.05	0.02	0.134	0.043
	12/08	3962.5	3321.8	0.06	0.01	0.238	0.033
	19/08	4787.5	4375.0	0.08	0.02	0.383	0.088
	26/08	4768.8	4778.2	0.10	0.02	0.477	0.096
	20/10	4451.0	4609.9	0.42	0.32	1.869	1.475
	24/05/82	3078.4	3764.7	0.77	0.34	2.370	1.280
						$\bar{B}$ = 3.053	P = 8.810
							P:$\bar{B}$ = 2.89

only lived longer at Musquash but also grew to a larger average size (9.5 mm) than at Avonport (8.6 mm). Reproduction at Musquash did not appear to be lunar-related as the density of 1 and 2 mm individuals increased steadily over a 6 week period from early July to mid-August.

Production

Annual production was determined to be about 22.1 and 8.8 g dry weight/m^2 for a year beginning in May of 1977 and 1981 at Avonport (Table 1) and Musquash (Table 2), respectively.

At Avonport production for the period of May to October was 19.2 and 20.5 g/m^2 in 1977 and 1978, respectively. These values are close to that of annual production indicating extremely low production during winter due to low densities and slow growth rate. Ice scour and periodic freezing of the mudflat cause heavy mortality over the winter. In 1977-1978 the density of *C. volutator* decreased from about 7700/m^2 to 2300/m^2 (70% mortality) from November to late March. The lower mortality (30%) observed at Musquash may result from the difference in water temperatures during that period with temperatures in the outer Bay of Fundy generally several degrees warmer, remaining above 0°C. As a result of the differences in mortality, production by the overwintering generation was very similar for the two locations, 10.2 g/m^2 at Avonport and 8.6 g/m^2 at Musquash.

Therefore the considerable difference in annual production lies with the disparity in production by the early summer broods. Relatively slow warming in May and June at Musquash may lead to the virtual failure of the first broods of the summer even though postwinter densities were very similar at the two sites. At Avonport the first brood in late May-early June increased the density 10 times. The equivalent brood release at Musquash resulted in less than 10% increase in density. It is this fast start in spring that allows the density of *C. volutator* at Avonport to exceed 20,000/m^2 averaged over the entire flat by the end of the summer. At Musquash the large numbers of juveniles released in July and August do not have sufficient time to mature and breed before water temperatures decrease below a threshold for reproduction, given as 6°C by McLusky (1968).

The turnover (production to biomass) ratio at Musquash (2.9) is similar to the ratios of 2.7 (Yeo 1978) and 3 to 4 (Birklund 1977) for the same species elsewhere. The ratio at Avonport (6.8) was slightly more than twice that found at Musquash. Waters (1979) reported that annual P:B ratios for bivoltine species should be about twice as high as for univoltine species. Winberg (1971) reported large differences in pairs of P:B ratios for the amphipods, *Gammarus lacustris, Gmelinoides fasciatus* and *Pontoporeia affinis* where the lower value was, as at Musquash, the result of a prolonged life cycle for the first 2 species and lower water temperatures for the third. Timing of life history dynamics, and hence production, has been cited by Wildish and Peer (1981) to vary with environmental factors, particularly temperature, food supply and photoperiod. The P:B ratios that they found for *Pontoporeia femorata* from the Atlantic coast of Nova Scotia (3.6 to 4.8) were considerably higher than those reported for a population from deep-water in the Baltic (0.78 to 2.08). They suggest that this difference may result from the cooler water temperatures in the Baltic and poorer food supply at greater depths.

The difference in turnover ratios may explain why fish feeding on the intertidal flat at Musquash (unpublished data) prey on *C. volutator* to a much lesser extent than do the same fish species in western Minas Basin.

Acknowledgements

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THE MACROINVERTEBRATE FAUNA ASSOCIATED WITH FIVE SAND FLATS IN THE NORTHERN GULF OF MAINE[1]

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The macroinvertebrate fauna of five sand flats in the northern Gulf of Maine was sampled during the summers of 1975 and 1976. Seventy-one putative species were identified. Annelids were the dominant taxon in terms of both numbers of species and numbers of individuals. Diversity, species per station and density varied greatly both within and between sites. The fauna was also markedly heterogeneous and it is not possible to define a characteristic sand flat fauna in this geographic region.

La faune des macroinvertébrés de cinq plaines sablonneuses situeés dans la partie nord du golfe du Maine fut échantillonnée pendant les étés 1975 et 1976. Soixante et onze espèces putatives furent identifiées. Les annélides constituent le taxon dominant aussi bien du point de vue du nombre d'espèces que du nombre d'individus. La diversité, le nombre d'espèces par station et la densité varient beaucoup, aussi bien pour chacun des sites qu'entre les différents sites. La faune est remarquablement hétérogène et il n'est pas possible de définir une faune caractéristique des plaines sablonneuses de cette région.

Introduction

Quantitative data on the invertebrate communities of intertidal habitats in the northern Gulf of Maine are generally lacking. In an attempt to correct this situation and provide needed information for planners and managers, the Maine State Planning Office instituted an invertebrate resource inventory in 1975. This inventory defined nine discrete intertidal habitats—sand beaches, gravel beaches, cobble beaches, boulder beaches, sand flats, mud flats, low energy rocky shores, high energy rocky shores and salt marshes. Each type of habitat was sampled at several representative sites along the northern Gulf of Maine coast from the Isle of Shoals to the Quoddy region with the goal of defining the invertebrate fauna of each habitat. This communication presents the results of the sand flat sampling program.

A sand flat is a protected environment predominantly made up of sand, but containing varying percentages of silt, clay and organic detritus. Flats have a slight grade and usually exhibit sand waves (Larsen & Doggett 1981). Sand flats represent less than 6% of the intertidal habitat area in the region (Larsen & Doggett, in press) but, in addition to being prime shellfish harvesting areas, they are important feeding areas for shorebirds, gulls, wading birds and water fowl. The flats in eastern Maine and southwestern New Brunswick are especially important for migrating semi-palmated plovers, semi-palmated sandpipers, short billed dowitchers and black-bellied plovers (U.S. Fish and Wildlife Service, 1980).

Data on this important habitat are particularly needed at this time because of the potential development of tidal power resources in the upper Bay of Fundy. These developments could modify the tidal regime throughout the Gulf of Maine and hence alter dynamic sedimentary environments such as sand flats (Greenberg 1979; Larsen 1981).

[1]Contribution No. 83010 of the Bigelow Laboratory for Ocean Sciences

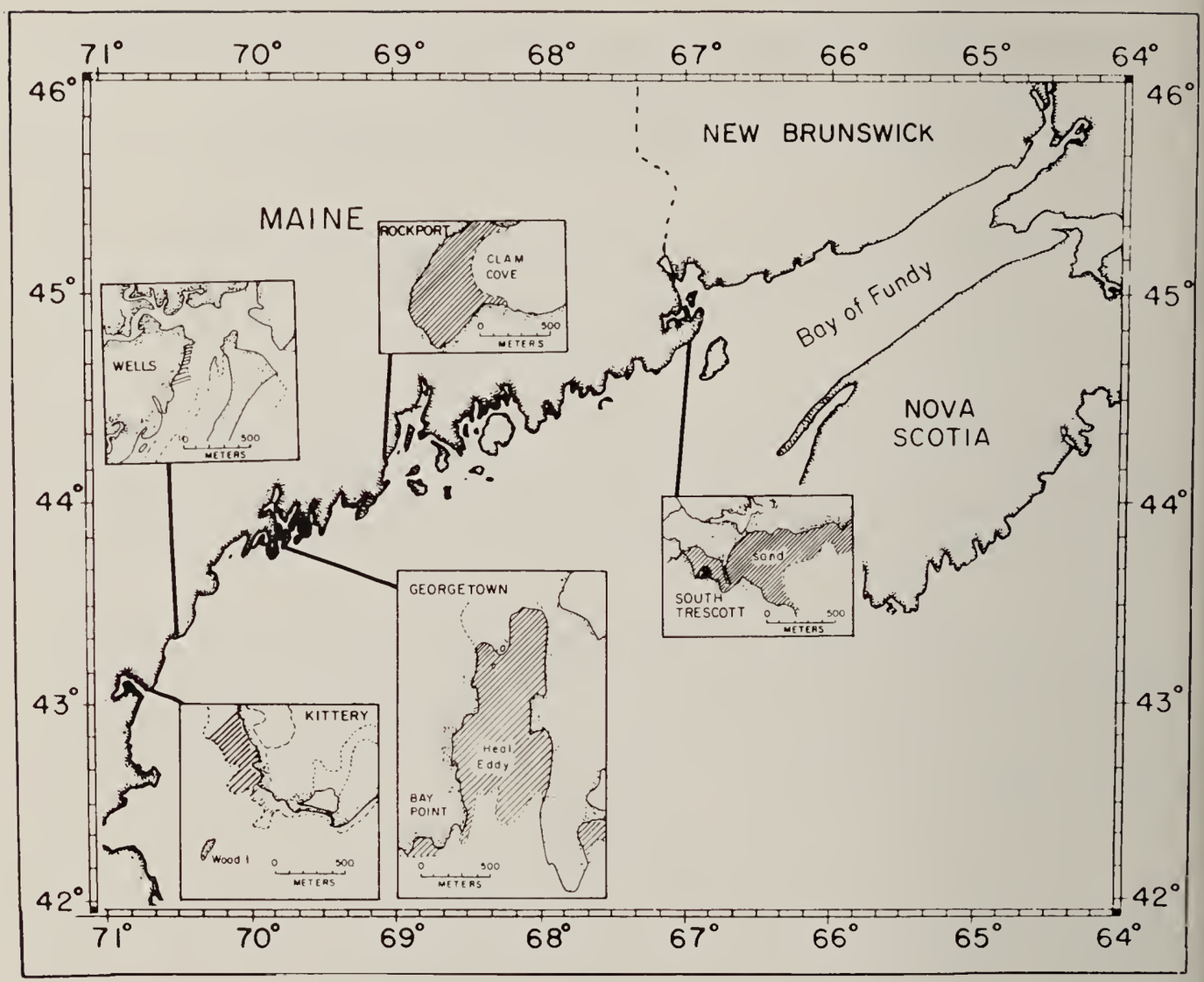

Fig 1. The locations of the sand flats studied in the northern Gulf of Maine.

Methods

Five sand flats representative of northern Gulf of Maine sand flats in terms of size, shape, slope and energy input were chosen for study (Fig 1) and sampled as close to spring tides as was practical. The sites selected and the dates of sampling were: Gerrish Island, Kittery (July 17, 1976); Wells Harbor, Wells (July 16, 1976); Heal Eddy, Georgetown (May 25, 1975); Clam Cove, Rockport (July 12, 1975); and Bailey's Mistake, Trescott (June 26, 1976).

Two transects were placed at each site. Four stations were occupied along each transect with the lowest station located at the low tide line and the highest station at the level of the last high tide. Intermediate stations were placed so as to dissect the intertidal zone into equal vertical segments. At each station a one-quarter meter squared quadrat with metal sides was forced into the sediment (Holme and McIntyre, 1971), and the enclosed area dug out to a depth of 15 to 20 cm. The sediment samples were transported in buckets to the laboratory or a field station and sieved on a 1.0 mm screen the day of sampling. The material remaining on the screen was fixed in 10% formalin containing the vital stain Rose Bengal. In the laboratory the samples were preserved in 70% ethanol and all organisms were removed, identified to the lowest taxonomic level practical (usually the species level), and counted. No attempt was made to identify nemerteans, nematodes, oligochaetes and insects to the species level.

Table I. Taxa found on northern Gulf of Maine sand flats.

	Kittery	Wells	Georgetown	Rockport	Trescott
Phylum Cnidaria					
Sertularia sp.					+
Phylum Rhynchocoela					
Unidentified Nemertea	+		+	+	+
Phylum Aschelminthes					
Unidentified Nematoda	+	+	+	+	+
Phylum Mollusca					
Hydrobia sp.			+		
Lacuna vincta			+		
Littorina littorea		+	+	+	
Nassarius trivittatus				+	
Odostomia bisuturalis				+	
Polinices heros	+		+		
Gemma gemma			+		
Macoma balthica	+	+	+	+	
Mya arenaria	+	+	+	+	+
Mytilus edulis		+	+	+	+
Spisula solidissima				+	
Tellina agilis	+			+	
Phylum Annelida					
Eteone longa	+	+	+	+	+
Phyllodoce sp.				+	
Pholoe minuta			+		
Glycera dibranchiata			+	+	
Aglaophamus verrilli	+				
Nephtys bucera	+				
Nephtys caeca	+	+	+	+	
Nephtys longosetosa					+
Exogene hebes	+		+	+	+
Nereis diversicolor	+			+	
Nereis virens		+	+		+
Capitella capitata	+				+
Heteromastus filiformis			+	+	
Clymenella torquata	+			+	
Maldanid	+				
Polydora sp.			+	+	
Polydora ligni			+		+
Pygospio elegans	+	+	+	+	+
Scolecolepides viridis		+	+	+	
Spio sp.		+			
Spio filicornis	+				
Spio setosa					+
Spiophanes bombyx	+		+	+	
Strebiospio benedicti			+	+	
Aricidea jeffreysii			+		

	Kittery	Wells	Georgetown	Rockport	Trescott
Paraonis fulgens			+	+	+
Lumbrineris fragilis				+	
Orbinia sp.	+				+
Scoloplos sp.	+		+	+	
Tharyx acutus			+		
Fabricia sabella			+		
Unidentified Polychaeta	+				
Oligochaeta		+	+	+	+
Phylum Arthropoda					
Balanus balanoides				+	
Leptocuma minor			+		
Chiridotea coeca			+	+	+
Chiridotea tuftsi			+		+
Edotea triloba			+	+	
Idotea phosphorea	+				
Corophium insidiosum		+	+		
Corophium volutator			+	+	
Uniola irrorata	+				
Gammarus sp.			+		
Gammarus lawrencianus			+		+
Gammarus oceanicus			+		
Acanthohaustorius millsi	+		+		
Haustorius canadensis	+				
Protohaustorius deichmannae	+				
Jassa falcata			+		
Psammonyx nobilis	+		+	+	+
Carcinus maenas			+	+	
Crangon septemspinosa	+		+	+	
Insecta Larva					+
Ant	+				
Phylum Hemichordata					
Saccoglossus kowalevskii	+				
Unidentified					+

Results and Discussion

A total of 71 putative species was encountered at the five sand flats (Table I). Annelids accounted for 46% of the species encountered, followed by the arthropods, molluscs and miscellaneous phyla which represented 30, 17 and 7% of the species respectively. Likewise, annelids were the numerically dominant taxon accounting for 71% of the individuals while the arthropods, molluscs and miscellaneous phyla comprised 15, 6 and 7% of the total individuals respectively. These figures stand in contrast to the results of sand beach studies in the region which show an overwhelming dominance of crustaceans (Croker et al. 1975).

A great deal of variability in the biological parameters of diversity (H^1 $\log_2$), species per station and density was manifested both within and between sites

Table II. The mean and ranges of diversity, number of species and density at each of the sites sampled.

Site	Diversity (H^1)	Total Species	Species Per Station	Density /m^2
Kittery	1.47(0.85-1.95)	30	9.4(4-16)	1,218,(316-3316)
Wells	1.19(0.0-2.16)	13	4.3(0-9)	314(0-832)
Georgetown	2.67(1.83-3.25)	43	15.3(9-21)	994(440-2080)
Rockport	1.77(0.88-2.78)	34	14.3(8-20)	2,044(464-4216)
Trescott	2.07(0.24-2.86)	22	12.3(11-17)	3,471(696-16,832)

(Table II). Mean values and ranges over all stations for these parameters were: diversity 1.82 (0.0-3.25); species per station 12 (0-21); and density 1510/m^2 (0-16,832). Averaging the values from all the stations at each sandflat produces a range in diversity of 1.19-2.67, in species per station of 4.3-15.3 and in density of 314-3,741/m^2.

The sandflats at Kittery and Wells exhibited the lowest values for diversity and species per station, and below average densities. The morphology of these flats differed from the others in that they were adjacent to tidal channels and presumably experienced higher levels of current and wave energy. This undoubtedly increases sediment instability limiting the number of species that can maintain populations. The flat at Georgetown had the highest diversity and species richness (Table II) but a rather low density. We have no explanation for this phenomenon. Moderate levels of diversity and relatively high densities were encountered at the two most eastern sites.

The sandflats also differed significantly in taxonomic composition. The Kittery sandflat was the only one numerically dominated by arthropods (Fig 2). Crustacean

Table III. The five most abundant species and their mean density/m^2 at each of five sand flats.

Kittery		Wells		Georgetown	
Protohaustorius deichmannae	406/m^2	*Mytilus edulis*	78/m^2	*Gemma gemma*	128/m^2
Acanthohaustorius millsi	393	Nematoda	75	*Scolecolepides viridis*	121
Pygospio elegans	186	*Mya arenaria*	68	Oligochaeta	116
Nereis diversicolor	115	Oligochaeta	32	*Nereis virens*	102
Tellina agilis	29	*Pygospio elegans*	22	*Acanthohaustorius millsi*	70

Rockport		Trescott	
Oligochaeta	770/m^2	*Exogone hebes*	2,763/m^2
Spiophanes bombyx	417	*Spio setosa*	245
Nematoda	306	*Chiridotea coeca*	89
Scolecolepides viridis	100	*Capitella capitata*	67
Clymenella torquota	77	Unidentified	66

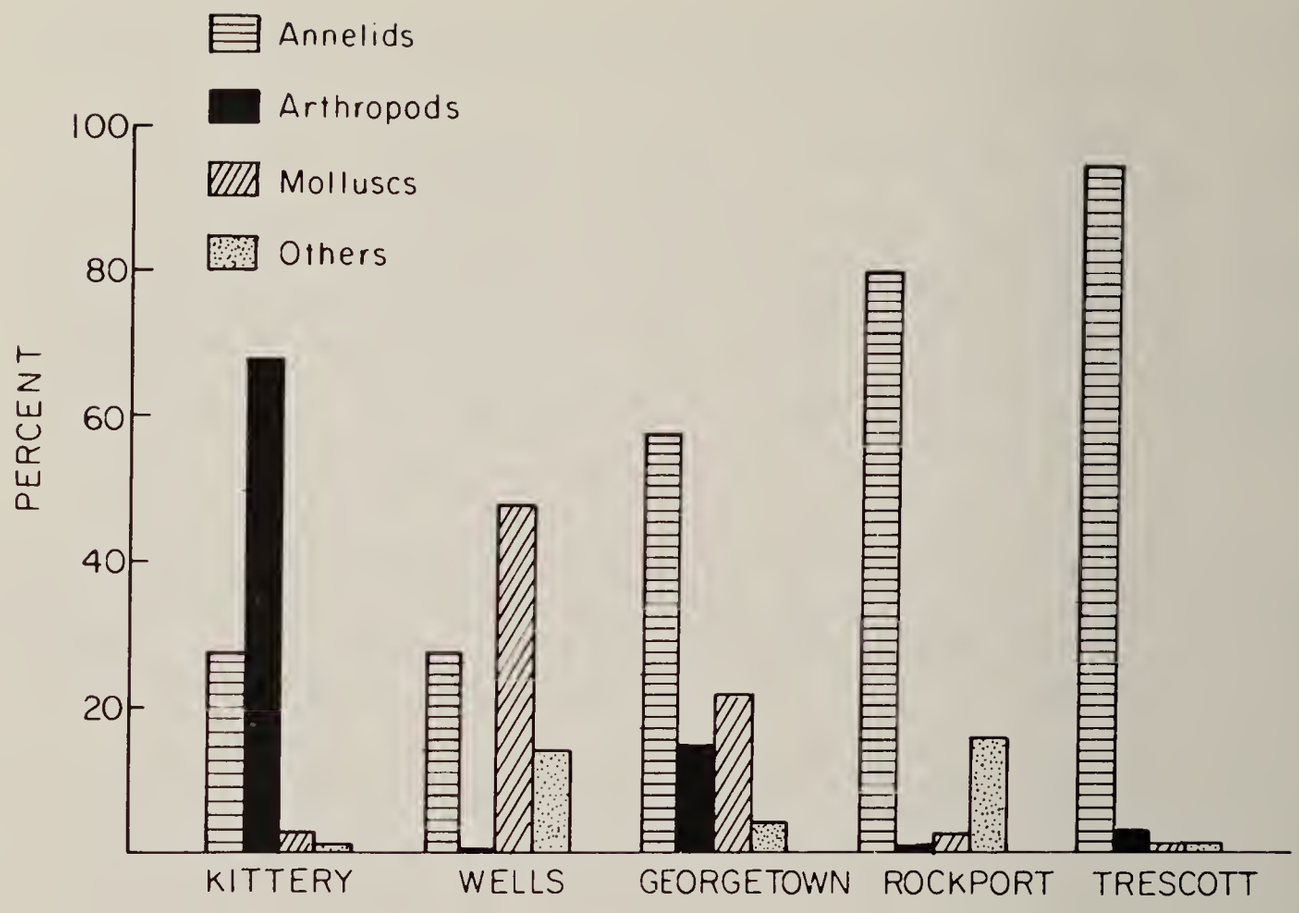

Fig 2. The percentage of individuals among four categories at each of five sand flats.

dominance was due to concentrations of the haustoriid amphipods, *Protohaustorius deichmannae* and *Acanthohaustorius millsi*, described (Croker et al. 1975) as being characteristic of sheltered and partly sheltered sand environments, respectively (Table III). The Wells sandflat was numerically dominated by molluscs, almost exclusively juvenile *Mytilus edulis* and *Mya arenaria*. This flat was characterized by large sand waves and it seems likely that the individuals encountered, especially of *M. edulis*, were washed in from adjacent environments and would not complete their life cycles on this flat. Only 13 species were found at this site (Table II).

The flats at Georgetown, Rockport and Trescott were dominated by annelids (Fig 2). With the exception of *Gemma gemma* and *Acanthohaustorius millsi* at Rockport, molluscs and amphipods were not numerically important at any of these sites. Consistent with the observation of Bousfield (1973) that the northern limit of haustoriid amphipods in the United States is central Maine, no haustoriids were found north of Rockport.

The invertebrate macrofauna of the five sand flats was markedly heterogeneous and it is not possible to define a characteristic sand flat fauna based on these results. The five most abundant species at each sampling site are listed in Table III. Nineteen taxa are represented, only five taxa being numerically dominant at more than one sand flat. These taxa are oligochaetes at Wells, Georgetown and Rockport, the haustoriid amphipod, *Acanthohaustorius millsi*, at Kittery and Georgetown, the polychaets, *Pygospio elegans*, at Kittery and Wells, and *Scolecolepides viridis* at Georgetown and Rockport.

The marked differences in community structure between individual sand flats, noted above in terms of number of species, diversity, density, and species domi-

nance, strongly suggest that ecological factors other than, or in addition to, gross sediment characteristics may be operative. Whether these factors are physical or biological in nature cannot be determined from the present results. Based on results from other intertidal habitats studied in the region, however, we do not believe that seasonal or interannual variation contributes significantly to the differences (Larsen & Doggett, unpublished).

Whereas most intertidal habitats are regarded to be physically controlled (*sensu*, Sanders, 1968), it is usually possible within a given geographic range to predict dominant species and/or characteristic fauna. This is true of sand beaches in the eastern United States (Croker et al. 1975) and mud flats in the northern Gulf of Maine (Larsen & Doggett, unpublished), but not of the sand flats studied. These flats, while superficially similar in appearance, are undoubtedly variously influenced by a wide range of physical factors that are not easily quantified. In addition, sand flats in this region are spatially isolated from one another unlike sand beaches south of, and mud flats north of, Cape Elizabeth, Maine. The nearly contiguous distribution of these latter habitats facilitates the development of a homogeneous fauna within a given geographic area. The disjunct distribution of sand flats in the northern Gulf of Maine may reduce recruitment between sand flats to the extent that community homogeneity does not develop. Further work on this important habitat with an emphasis on mechanisms influencing community development is definitely needed.

Acknowledgements

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INTERTIDAL *ZIRFAEA CRISPATA* (L.) BURROWS AS INDICATORS OF FLUCTUATING LOW WATER LEVEL IN MINAS BASIN, NOVA SCOTIA

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Colonies of the great piddock *Zirfaea crispata*, rock-boring clam, have created numerous conical burrows in shale terraces at Cape Blomidon, Minas Basin, Nova Scotia. Carbon 14 dating indicates that valves can remain trapped in the rock cavities for at least 900 years. Higher on the shore to about 80 cm above the present populations of live *Zirfaea* are older burrows eroded nearly to their bases. Shell fragments from these cavities were too small to date, but could be near 1200 years old. Interpretation of this sequence of burrows indicates a rise and subsequent lowering of extreme low water level in Minas Basin. A slowing of the rate of rise in mean sea level in combination with an increase in megatidal amplitudes is proposed as a hypothesis to explain these observations.

Des colonies de *Zirfaea crispata*, une huitre freuse, ont creusé de nombreux trous coniques dans les terrasses de schiste argileux du Cap Blomidon, Bassin Minas, Nouvelle-Ecosse. La datation au C^{14} indique que les valves peuvant demeurer emprissonnées dans les cavités rocheuses pour au moins 900 ans. Des trous plus vieuz, érodés presque jusqùa leurs bases, sont localisés dans la partie plus élevée du rivage jusqu'a une hauter de 80 cm au-dessus des populations actuelles vivantes de *Zirfaea*. Les fragments de coquilles provenant de ces cavités sont trop petits pour être datés mais pourraient être agés de presque 1200 ans. L'interpretation de cette sequence de cavités indique qu'un élévation suivie d'une abaissement du niveau des eaux basses extrêmes s'est produite dans le Bassin Minas. Un ralentissement de la vitesse d'élévation du niveau moyen de la mer combiné avec une augmentation des amplitudes mégatidales constitute les fondements d'une hypothèse qui permettrait d'expliquer ces observations.

Introduction

The accumulated evidence for a progressive rise in mean sea level in eastern Canada over the past 6,000 years has been summarized by papers in Ogden and Harvey (1975) and by Amos (1978). These papers emphasize high water levels because the biological evidence for this boundary is readily evident as successive salt marsh horizons. Investigations at Fortress Louisburg, Nova Scotia (Grant 1975) demonstrated a rise in high tide levels of 0.8 m over the past 250 years accompanied by a nominal change in tidal range from 6.05 ft. to 6.00 ft. In the Bay of Fundy, there is clear evidence to indicate a gradual increase in daily tidal amplitude (range) over the last several thousand years (Grant 1970; Amos 1978). However, little is known of the relative position of low water levels over this same time period.

Amos (1978) proposed that if the development of the present large tides in the Bay of Fundy and Minas Basin was accompanied by a proportional rise in position of mean sea level then the result would be a relatively fixed level of low water during the last 6300 years or so. An unusual opportunity to test this hypothesis and to fix the position of low water over a period of perhaps the last 1200 years was pursued at Cape Blomidon, Minas Basin. The great piddock *Zirfaea crispata* (Linnaeus 1758), a rock-boring clam, is common at that site and as the sturdy valves remain entrapped in their rock chambers for hundreds of years, it seemed reasonable to attempt radio-carbon dating of the old burrows as a means of deciphering fluctuations in sea levels. Andersen (1971) was able to date *Zirfaea* valves from Danish clay deposits to 34,500 years B.P.

Fig 1. Aerial view, from altitude of 150m, of Cape Blomidon shale terraces, which to the right are buried beneath basalt rock slides. Tide is an extreme low water spring of 20 August 1978, and the vertical distance from water's edge (W) to strand line (S) is about 16 m. Elevations at survey station sites No. 3A to No. 9 are provided in Table II.

Study Area

At the cliff base of Cape Blomidon, Minas Basin, the lower intertidal zone is a series of terraces (Fig 1) which contain interbedded Triassic sandstones and shales (Crosby 1962). A detailed description of the study site has already been published (Bleakney, Robinson & Waugh 1980) and the transect line and station sites established then (1978) were also used for this study. The terraces on which the *Zirfaea* clams were found vary from 2 m to 20 m in width and the terrace faces from 25 cm to 45 cm in height. The terraces run approximately parallel to the shore and the lower terraces have been extensively burrowed by *Zirfaea*. (We know of one other similar area in the western Minas Basin, 0.6 km to the south at Lyon's Cove. Also, from hearsay accounts, there is the possibility that the area around Five Islands, along the north shore of the Minas Basin, has experienced similar *Zirfaea* activity). The horizontal distance that *Zirfaea* burrows occupy at Cape Blomidon is approximately 53 m in width. On the vertical scale, they reach 135 cm above extreme low water. When one traverses the terraces, it is immediately evident that the shallow depressions that constitute the uppermost burrows are but remnants of a once dense population of clams. There are now neither living *Zirfaea* nor deep burrows on these terraces, indicating that low water levels have receded relatively recently.

Materials and Methods

The Great Piddock is a large boring clam (shell length 5 to 7 cm, dry shell weight 12 to 20 g which, on the shores of the northwest Atlantic (personal com-

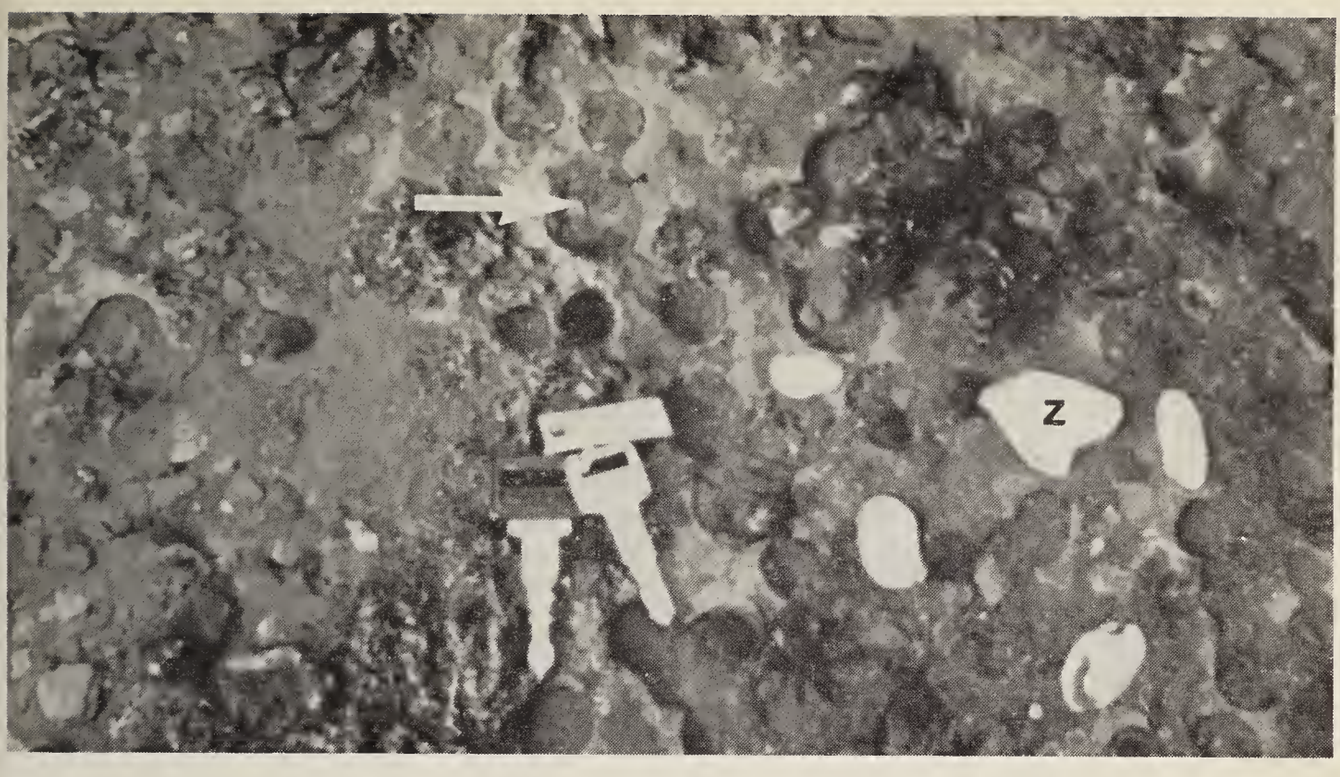

Fig 2. Burrows of *Zirfaea crispata* in Blomidon shale at station No. 7 and a portion of one valve at Z. The largest orifice at center of photo (arrow) is the basal chamber of a burrow exposed now after hundreds of years of erosion have removed about 18 cm of rock.

munications from Dr. Ruth D. Turner, Museum of Comparative Zoology, Harvard University, Mass.; Dr. John Evans, Memorial University, Newfoundland; and Dr. Derek Davis, Nova Scotia Museum of Science, Halifax) rarely lives above extreme low water. The fact that this species is exposed by extreme low-water tides in Minas Basin is not unexpected because local megatidal spring tides expose a wide margin of typically sublittoral fringe habitats on these gently sloping shores (Bleakney 1972). At Cape Blomidon such species as the deep sea scallop *(Placopectin magellanicus* (Gmelin), the ten-ridged whelk *(Neptunea decemcostata* (Say), the leafy bryozoan *(Flustra foliacea* (L)) and kelps *(Laminaria* spp.) become fully exposed during extreme low-water springs. On adjacent broad intertidal flats in Minas Basin, the stranding of fish is a common phenomenon during such tides (Bleakney & McAllister 1973).

At Cape Blomidon, *Zirfaea* have excavated vertical burrows in shale to depths of 22 cm (Fig 2). As the clams grow, they progressively deepen and widen their burrows creating inverted cone-shaped cavities with opening diameters of only 1 to 1.7 cm, potential depths of 20 to 22 cm, and basal maximum widths of 4.3 to 4.5 cm. After a life span of only 4 to 7 years (Allen 1969), they die and the paired valves are trapped in the shale chambers which soon become packed with detritus and silt. Removal of the valves will not occur until perhaps 8 to 16 cm of erosion has taken place, thereby enlarging the orifice enough to accommodate removal of the tightly fitting valves. Between September of 1978 and November of 1979, 124 burrows were measured (Table I) and many others were examined. The amount of erosion at each measured burrow (Table I) was estimated by best fitting each burrow's dimensions to a set of diagram outlines of lengthwise sections of burrows which were derived from detailed measurements of burrows housing living *Zirfaea* of various body sizes. Even the largest live *Zirfaea* did not have a burrow orifice greater than 1.7 cm. However, since many of the old burrows had orifice diameters in the order of 2.5 to 3.5 cm it was evident that a considerable amount of original rock substrate had been removed through natural erosion.

Table I Characteristics of 124 burrows examined, with data on *Zirfaea crispata* and their remains.

Station No. and Height Above Datum	Burrow Depth (cm)	Orifice Diam. (cm)	Estimated Rock Eroded (cm)	Presence of Valves (P) or clams (L)	Valve Weight (gm)	Valve date C^{14} Yrs.B.P.(1950)
3A (n=8)	2.0	2.5	8.0			
(+ 135 cm)	6.8	2.5	8.0	P	1.3	
	2.5	3.0	10.0			
	5.5	3.0	11.0			
	5.8	3.0	11.0			
	5.5	3.0	11.0			
	3.3	3.3	13.0			
	4.0	3.3	13.0			
3 (n=5)	5.2	3.2	12.5	P	3.7	
(+ 110 cm)	4.0	4.0	18.0			
	2.0	4.3	20.0	P	3.5	
	10.0	1.2	—	L		
	12.5	1.3	—	L		
4 (n=32)	12.5	1.8	1.0	P	11.5	380 ± 70
(+ 90 cm)	8.0	2.1	4.0	P	2.8	200 ± 95 processed as a single unit
	8.5	2.0	4.0	P	2.3	
	8.0	2.0	4.0	P	2.15	
	4.0	2.1	5.2			
	7.0	2.2	6.0	P	3.3	
	4.9	2.4	6.5			
	1.0	2.3	7.0			
	2.8	2.5	7.5			
	5.5	2.5	7.5	P	3.5	
	2.3	2.7	8.5			
	3.0	2.7	8.5			
	3.2	2.7	8.5			
	2.8	2.8	9.5			
	2.0	2.8	9.5			
	3.5	2.8	9.5			
	5.4	2.8	9.5			
	2.7	2.8	9.5			
	3.2	2.8	9.5			
	2.0	2.8	9.5			
	4.4	3.1	10.0	P	4.0	380 ± 125
	4.2	2.9	10.0	P	2.2	
	2.0	2.9	10.0			
	2.0	3.0	10.5			
	2.7	3.0	10.5			
	4.5	3.0	11.0	P		
	3.0	3.0	11.0			
	3.0	3.0	11.0			
	3.2	3.1	11.5			

	3.2	3.2	12.0			
	3.5	3.2	12.0			
	3.5	3.5	14.5			
5(n = 42)	4.5	1.0	0.0			
(+ 75 cm)	1.0	1.5	2.0			
	1.5	1.5	2.0			
	3.5	1.5	2.0			
	3.0	1.3	2.5			
	3.0	1.5	2.5			
	3.0	1.5	2.5			
	3.5	2.0	5.0			
	3.0	2.0	5.0			
	2.0	2.0	5.0			
	5.0	2.0	5.0			
	1.0	2.0	5.0			
	3.0	2.0	5.0			
	5.0	2.0	5.0			
	2.5	2.0	5.0			
	10.0	2.0	5.0	P	5.1	25 yrs max
	7.5	2.0	5.5	P	3.3	
	6.0	2.5	7.0			
	4.0	2.5	7.5			
	4.5	2.5	7.5			
	4.5	2.5	7.5			
	5.0	2.5	7.5			
	5.0	2.5	7.5	P	2.5	
	10.0	2.3	7.5	P	5.0	25 yrs max
	3.5	2.5	8.0			
	3.0	2.5	8.0			
	3.5	2.5	8.0			
	2.0	3.0	10.0			
	4.5	3.0	11.0			
	3.0	3.0	11.0			
	3.0	3.0	11.0			
	3.0	3.0	11.0			
	3.0	3.0	11.0			
	5.0	3.0	11.0			
	4.0	3.0	11.0			
	3.0	3.0	11.0			
	4.0	3.0	11.0			
	4.0	3.0	11.0			
	4.2	3.0	11.0	P		
	7.0	3.0	11.5	P	6.5	25 yrs max
	2.0	3.5	14.5			
	4.5	3.5	16.0			
6(n = 15)	12.0	1.0	—	L		
(+ 58 cm)	12.0	1.0	—	L		
	21.0	1.2	—	L		
	22.0	1.7	—	L		
	17.5	2.5	7.0			
	4.2	2.4	7.0			

	9.0	2.5	7.5			
	5.0	2.5	7.5			
	17.5	3.0	(5-10?)	P	5+	210 ± 95
	5.0	2.7	8.0			
	9.0	3.0	11.0	P	5	865 ± 100
	7.0	3.0	12.5			
	3.8	3.5	14.5			
	5.2	3.5	16.0	P	5.2	485 ± 105
	5.5	3.7	16.0			
6A	7.5	3.0	11.0	P	3.8	
(+ 41 cm)	7.0	3.5	14.0	P	2.0	
	21.0	1.7	—	L		
6B	18.0	1.1	—	L		
(+ 35 cm)						
7(n = 16)	9.8	1.0	0.0			
(+ 35 cm)	10.5	1.5	1.5			
	14.0	2.2	4.0	P	11.15	50 yrs max
	6.5	2.1	5.0			
	9.0	2.2	5.0			
	9.0	2.0	5.0	P	5.4	
	6.7	2.4	7.0			
	10.0	2.5	7.5			
	5.5	2.6	8.0	P	2.0	
	10.0	2.5	8.0	P	7.2	
	9.0	2.7	8.0	P	8.2	865 ± 75
	4.5	3.0	11.1			
	7.0	3.0	11.0	P	0.2	
	2.3	3.2	12.5			
	4.8	3.4	14.0			
	4.0	3.5	14.5			
8	6.0	3.2	11.0	P	9.0	25 yrs max
(+ 25 cm)						
9	7.0	2.9	10.0	P	5.8	
(+ 15 cm)						

Results and Discussion

Table II depicts the relative elevations of *Zirfaea* burrows from observed extreme low water level (based on observations during 9 extreme low-water spring tides) and the maximum densities that were noted at several elevations. Live *Zirfaea* were evident up to Station No. 6 (+58 cm) but in spite of flushing of numerous burrows (Bleakney, Robinson & Waugh 1980), none were observed above that level (with one exception) although old burrows pocketed the rock up to 135 cm above low water. That exception was in an outflow trough that drained waters from No. 3A terrace (+135 cm). On the continually watered slope of this terrace face were old burrows from which an estimated 12 to 20 cm of rock had been eroded (Table I, Station No. 3) but there were also several live *Zirfaea*, two of which were chiseled out of the shale. It is evident that *Zirfaea* veliger larvae are settling on the terraces but that above +60 cm they find few areas suitable for survival. This again indicates that extreme low water has receded, but the reported evidence in Nova Scotia indicates rising sea levels (Ogden & Harvey, 1975; Amos, 1978).

Table II. Distribution of *Zirfaea crispata* and vertical distances between collecting stations relative to estimated low water, based on observation of 9 extreme low-water spring tides.

Tidal Height cm	Station No.	Vert. Diff. cm	Max. Density m^2	Comments
140				
	3A.		6	**oldest identifiable burrows
130				
		25		
120				
110	3. . . . . (5 only)			isolated group of live *Zirfaea* in out-flow off above terrace.
		20		
100				
90	4.		26	no live *Zirfaea*.
		16		
80				
	5.		158	no live *Zirfaea*.
70				
		16		
60	6.		22	**present upper limit of the live *Zirfaea* population.
		17		
50				
	6A.			
40		6		
	6B, 7.		75	
30		10		
	8			
20		10		
	9			
10				
		15		
0	estimated extreme low water			

The older upper terraces of *Zirfaea*-perforated rock are subject to intertidal wave and ice erosion. Attrition rates of the essentially subtidal stations No. 7 to No. 9 must be less than at those terraces exposed intertidally. The burrows at these lowest levels are of every depth and dimension and would indicate a continuous utilization of the terraces by *Zirfaea* for a thousand or more years. Carbon 14 dating of the entrapped *Zirfaea* valves should have provided some answers to the ages of these burrows and thus the rate at which the shore erosion is taking place in a vertical plane. Unfortunately, the C^{14} results do not encourage interpretation with any confidence (Table I). There seems no consistent correlation of age with burrow depth, or amount of erosion, or weight of valves, or height above mean low water. Additionally, because the Dalhousie University Carbon Dating Laboratory required at least 5 g of shell per sample, those smaller samples from the highest levels could not be dated. Perhaps even the 5 g samples used were too small or too contaminated. (Hopefully, the methodology or the machine itself was at fault.) All we can conclude is that some *Zirfaea* valves weighing over 5 g have remained en-

trapped in burrows for nearly 900 years, and that the older, thinner valves weighing only 2 and 3 gms might represent another 300 years. That the valves become reduced is not surprising as there are at least 88 species of metazoan animals that will take up residence in vacated, detritus-filled, *Zirfaea* burrows, and their activities must contribute to physical and chemical attrition (Bleakney, Robinson & Waugh 1980).

Of particular interest is supporting evidence for fluctuating low water levels from an area 11.5 km south of Cape Blomidon on the intertidal flats of Evangeline Beach. An extensive bed of oysters *(Crassostrea virginica)* which were growing under subtidal or extreme low water conditions about 3800 years B.P., are now 1.5-2.0 m above extreme low water (Bleakney & Davis, 1983). It follows that even though the upper limit of *Zirfaea* would have been even more restricted 3800 years ago because of then lesser tidal amplitudes, this species should nevertheless have ranged at least as high as the oysters, which would be nearly 2 m higher than present extreme low-water level at Blomidon. That would be about 60 cm above the 140 cm limit of the oldest evident burrows at Blomidon today. What was the eventual upper limit of low water in Minas Basin before it began to recede? How recently did that reversal take place? The answer to both questions (provided the problems with C^{14} dating can be identified and overcome) may lie beneath that talus slope of basalt rocks evident in Figure 1 where the shale terraces and *Zirfaea* burrows have been buried and protected from erosion.

Conclusions

Amos (1978) calculated rising sea-level curves for Minas Basin from a series of dated, high-water marsh horizons and from extrapolated mean sea levels. He lacked information for complementary low-water positions. He concluded that the progressive inundation in Minas Basin was a function of an increase in tidal range (50%) and a rise in apparent mean sea level (50%), and consequently low water levels remained static.

Biological evidence presented here indicates receding low-water levels. This can be accommodated within Amos's general thesis by assuming the rate of rise of mean sea level has recently slowed. This, in combination with ever-increasing tidal amplitudes, would have generated progressively lower tidal levels in recent times. Thus, whereas sea level rise in most areas assumes high water, mean sea level and low water are rising in conjunction with one another, the accelerated evolution of megatidal amplitudes in Minas Basin has actually exceeded mean sea level rise and has thereby depressed low-water limits to below that of the *Zirfaea* of 400 yrs B.P., 900 yrs B.P. and even below the 3800 yrs B.P. oyster bed.

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FUNGI OF THE BAY OF FUNDY V: FUNGI FROM LIVING SPECIES OF SPARTINA SCHREBER

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Some 26 species of fungi were isolated from living *Spartina* species in the Bay of Fundy. Most (22 species) were Deuteromycetes, 3 were Ascomycetes. One Basidiomycete was identified. Most of these fungi have been reported before on marine angiosperms. This is the first report of *Pleospora spartinae* outside the United Kingdom. The fungi reported are discussed in terms of their possible relationship to terrestrial fungi.

Quelques 26 espéces de champignons furent isolées à partir d'espéces vivantes de *Spartina* de la baie de Fundy. La plupart (22) sont des Deutéromycètes, 3 des Ascomycétes. Un Basidiomycète fut identifié. La présence, sur des Angiospermes marins, de la plupart de ces champignons a déjà été signalée auparavant. Cependant, c'est la première fois que *Pleospora spartinae* est signalé en dehors du Royaume Uni. La possible relation entre les champignons rapportés ici et les champignons terrestres est discutée.

Introduction

There have been a number of studies of fungi associated with *Spartina* species in eastern North America (Boland & Grund, 1979; Gessner, 1977; Gessner & Goos, 1973; Gessner & Kohlmeyer, 1976). These studies have involved collections of living and dead material of *Spartina* species, but none have attempted to examine the fungi associated with leaves, stems and roots of living plants in the manner of several studies of marine angiosperms in the United Kingdom (Dickinson, 1965; Lindsey & Pugh, 1976; Pugh & Williams, 1968; Sivaneson & Manners, 1970). No studies have been reported of fungi associated with *Spartina* species in New Brunswick.

The Bay of Fundy is noted for its high tides and other unusual hydrographic factors, details of which are given by Bailey (1957) and Hachey (1975). There are extensive salt marshes along the Bay of Fundy in New Brunswick and Nova Scotia (Thomas, 1983).

This paper reports on fungi found on living plants of several species of *Spartina* from the Bay of Fundy.

Materials and Methods

Samples from healthy *Spartina* species were taken from sites noted in Table I in July and early August, 1980 and treated in two ways: (1) Seawater incubation: 12 screw-capped bottles each containing 100 mL sterile artificial seawater (ASW)

*C.B.R.I. contribution No. 1372

Table I Details of sampling sites.

Station	Name	Location (N.W.)	High Tide Salinity (‰)	Tidal Range vertical (m)	Tidal Range horizontal (m)
1	Alma Beach	45° 36′ 64° 57′	28-31	9.1	1000
2	Point Wolfe	45° 32′ 65° 01′	20-25	9.0	500
3	St. Martins	45° 21′ 65° 33′	28-31	7.8	100
4	Taylor's Peninsula	45° 13′ 66° 08′	28-31	6.7	500
5	St. Andrews Harbour	45° 04′ 67° 03′	30-32	6.0	25

NOTE: Surface temperature of Bay of Fundy annual range 3-12°C.

(Lyman & Fleming, 1940) adjusted to 28‰ salinity and with 100 mg/L chloramphenicol were inoculatd with pieces of the roots, stems and leaves respectively, of *Spartina* species (with no nitrogen compounds or phosphate added). These were incubated at 12°C for 4 months. At the end of that period, one-ml aliquots of the fluid were plated on seawater Potato Dextrose Agar (SPDA) and Seawater Agar (SA) (Johnson & Sparrow, 1961) and the fungi isolated. In addition, the remaining fluid and the piece of plant were poured into Petri plates 100 x 15 mm and allowed to dry at 20°C for 6 wk. As fungi developed on the plant and/or the surface of the seawater, they were isolated and/or examined directly.

(2) Moisture-Chamber incubation: Samples of the roots, stems and leaves of *Spartina* species were collected in sterile plastic bags and transferred to the laboratory under cold conditions. These were placed individually in Petri plates containing a piece of Whatman No. 1 filter paper moistened with ASW adjusted to 28°/oo salinity and with 100 mg/L chloramphenicol (with no nitrogen compounds or phosphate added). These were incubated for four months at 12°C with periodic remoistening with sterile distilled water. As fungi developed on the plant or the filter paper, they were isolated on SA and/or examined directly.

Results

Fungi isolated by both methods above and the part of the plant yielding the fungi are listed in Table II. Virtually all of the Deuteromycetes isolated have been reported previously on marine angiosperms (Dickinson, 1965; Gessner & Goos, 1973; Lindsey & Pugh, 1976; Pugh & Williams, 1968; Sivaneson & Manners, 1970). The Ascomycetes *Buergenerula spartinae* and *Leptosphaeria albopunctata* have been reported on *Spartina* in Nova Scotia (Boland & Grund, 1979) and eastern Canada (Gessner & Kohlmeyer, 1976). *Buergenerula spartinae* was reported on *Spartina* in New Brunswick (Kohlmeyer & Kohlmeyer, 1979). *Leptosphaeria albopunctata* may be a first report on *Spartina* from New Brunswick (cf. Kohlmeyer & Kohlmeyer, 1979; Miller & Whitney, 1981a). The collection of *Pleospora spartinae* is thought to be the first report for this fungus outside the U.K. *Sporobolomyces roseus* has been reported on *Hippophaë rhamnoides* L. from coastal England (Pugh & Lindsey, 1975).

Discussion

Consistent with other studies of the fungal flora of living marine angiosperms, there are many 'terrestrial' Deuteromycetes on the *Spartina* species reported in this paper. A number of common microfungi on living marine angiosperms are listed in Table III. Of the 14 species from six studies of four marine angiosperms about half were common on the plants. This included such fungi as *Cladosporium (C. herbar-*

Table II Fungi isolated from living *Spartina* species.

Deuteromycetes	Leaves	Stems	Roots
Alternaria alternata[1] (Fr.) Keissler	xx[2]	xx	x
Botrytis cinerea Persoon	xx		
Cladosporium cladosporioides (Fresen.) de Vries	xx		xx
C. herbarum (Pers.) Link *ex* Gray	xx	x	x
C. macrocarpum Preuss	x		
C. resinae (Lindau) de Vries			x[3]
Dendryphiella salina (Suth.) Pugh & Nicot	xx	xx	
Fulvia fulvum (Cooke) Ciferri	xx	x	
Fusarium oxysporum Schlecht.	x		x
Gliocladium catenulatum Gilman & Abbot	x		
G. roseum (Link) Thom	xx	xx	xx
Monodictys castaneae (Wallr.) Hughes	x		
Mucor sp.			x
Penicillium brevi-compactum Dierckx			x
P. lividum Westling	x	x	
P. notatum Westling			x
P. puberulum Bainier	x		
Phialophora melinii (Nannf.) Conant	x		
Stemphyllium sp.	x		
Trichoderma album Pers.	x		
pink yeast-like organisms	x	x	x
sterile sp.	x		x
Ascomycetes			
Buergenerula spartinae Gessner & Kohlm.			xx
Leptosphaeria albopunctata[1] (Westend.) Sacc.		x	
Pleospora spartinae[1] (Webster & Lucus) Apinis & Chesters		x	
Basidiomycetes			
Sporobolomyces roseus Kluyver & Van Niel	x		
isolates with clamp connections	x		x

NOTES:
[1]see taxonomic part
[2]x refers to 1-5 isolations, xx>5
[3]oil-contaminated marsh

um and *C. cladosporioides* are closely related; de Vries, 1952) and *Aureobosidium pullulans*[1] which are considered benign endophytes, and species of *Alternaria, Botrytis* and *Fusarium* which are pathogenic in the terrestrial phylloplane (Dickinson, 1976).

In the present study, *Dendryphiella salina* and *Gliocladium roseum* were frequently isolated. *D. salina* is a common marine fungus in salt marshes (Pugh, 1974) and wood (Miller & Whitney, 1981a), and *G. roseum,* also common in salt marshes, is considered by Pugh (1974) and Miller & Whitney (1981b) to be amphibious (i.e., terrestrial and marine).

It appears that the phylloplane fungi of marine angiosperms are similar to their terrestrial counterparts, with the addition of some marine species. It is possible that

[1]Meyers, *et al.* 1967, state that there can be a pink yeast-like stage of *A. pullulans* (DeBary) Arnaud in marine systems. Such isolates were found in this study.

Table III Common microfungi on living marine angiosperms.

	Spartina	Halimone[4]	Salsola[5]	Hippophaë[6]
Alternaria alternata	1,2,3	x	x	x
Aureobasidium pullulans				x
Botrytis cinerea	1,2,3			x
Cephalosporium spp.	2,3	x	x	
Cladosporium cladosporioides	1			
C. herbarum	1,2,3	x	x	x
Dendryphiella salina	1	x		
Fulvia fulvum	1			
Fusarium spp.	2,3	x	x	x
Gliocladium roseum	1			
Penicillium frequentans West.	3			
Phoma spp.	2			
Septoria sp.	2			
Trichoderma koningii Oudem.	3			

NOTES:
1. this work
2. Gessner and Goos, 1973
3. Sivanesan and Manners, 1970
4. Dickinson, 1965
5. Pugh and Williams, 1968
6. Lindsey and Pugh, 1976

some of the terrestrial fungi might be marine-adapted strains (Miller & Whitney, 1981b; Pugh & Lindsey, 1975). The range of microfungi on the phylloplane of *Spartina* species is different from that isolated from littoral seaweeds from the same sampling stations (Miller & Whitney, 1981c).

Most of the microfungi were isolated from the leaves, with only a few from stems and roots (Table II). Sivanesan & Manners (1970) tested a number of *'Spartina'* microfungi for growth under conditions of low O_2 and high sulfate/sulfide to stimulate a salt marsh rhizosphere. *Gliocladium roseum* and two species of *Mucor* were found to tolerate these conditions and both fungi were found from *Spartina* roots in the present study. The fungi *Cladosporium* (four species) and *Alternaria alternata* were found on the roots of *Spartina* in this study, and were reported able to tolerate high sulfate/sulfide but not low 0_2. The fungus *Botrytis cinerea*, found only on leaves of *Spartina* (Table II), was reported unable to tolerate low 0_2 or high sulfate/sulfide. Thus, within the group of fungi found on living *Spartina*, there is a sub-group which is adapted to the salt marsh rhizosphere.

The low number (three) of Ascomycetes found in this study is consistent with the findings of other studies. This is in contrast to those which examined dead material, from which many Ascomycetes were found (e.g., Boland & Grund, 1979; Gessner & Kohlmeyer, 1976). *Buergenerula spartinae* was previously reported on living *Spartina* by Gessner (1977). *Leptospheria typharum* (Rabenh.) Karst. and *Pleospora herbarum* (Fr.) Rabenh. have been reported on living *Spartina* and *Halimione* respectively (Gessner & Goos, 1973; Dickinson, 1965).

Taxonomic Part

The following species from Table II require taxonomic explanation or are first reports for New Brunswick.

Alternaria alternata (Fr.) Keissler (Ellis, 1971). In the course of the present work and earlier studies of marine wood, seawater and seaweeds (Miller & Whitney, 1981a,b,c) approximately 50 isolates of an *Alternaria* species identified as *A. alternata* were isolated. Sutherland (1916) described a marine *Alternaria, A. maritima*. This species was accepted by many authors (e.g. Johnson, 1959; Jones, 1962; Neish, 1970; Curran, 1975). Several other authors have questioned the position of this species (e.g. Hughes, 1969; Joly, 1964). Johnson & Sparrow (1961) stated "It must be admitted that other than the fact that the fungus was originally described from, and has subsequently been found in, a marine habitat, there is little reason for considering it to be a true marine species. *Alternaria maritima* possibly could be assigned, if one were inclined to do so, to any one of several known terrestrial species in the genus". Sutherland (1916) described a green appearance of *A. maritima* that is not characteristic of *A. alternata*. *Alternaria alternata* is the most similar accepted species with respect to conidia size, shape and appearance to the marine isolates (Table IV). However, most of the marine isolates in these studies are definitely green in culture as opposed to the "usually black or olivaceous black or sometimes gray" of terrestrial isolates (Ellis, 1971; in the type description of *A. alternata*) even after several transfers on either saline or freshwater media. Prof. E.B.G. Jones (Portsmouth Polytechnic) also reports green *Alternaria* from marine sources (pers. com., 1980). The marine isolates discussed have consistently had rough conidia, whereas *A. alternata* from terrestrial sources may have either smooth or rough conidia (cf. Jones, 1962). In addition, about 10% of the marine isolates showed poor sporulation on freshwater media (Table IV). Kohlmeyer and Kohlmeyer (1979) reject *A. maritima*, considering it a *nomen dubium* (*cf. Bot. Mar.* 23: 622, 1980). However, pending further study it seems likely that there is an *Alternaria alternata* var. *maritima*.

Leptosphaeria albopunctata (Westendorp) Saccardo, Syll. Fung. 2, 72, 1983.
Ascospores 26-30 (–40) x 8-10 μm, mostly seven-septate. Previously reported on wood in New Brunswick (Miller & Whitney, 1981a; Kohlmeyer & Kohlmeyer (1979 and Nova Scotia (Neish, 1970) and on *Spartina* in Nova Scotia (Boland & Grund, 1979). Collections on *Spartina* were similar to our collection on wood (Miller & Whitney, 1981a), except some ascospores were larger.

Pleospora spartinae (Webster & Lucus) Apinis & Chesters, Trans. Br. Mycol. Soc. 44, 1961, Figure 1, 2.

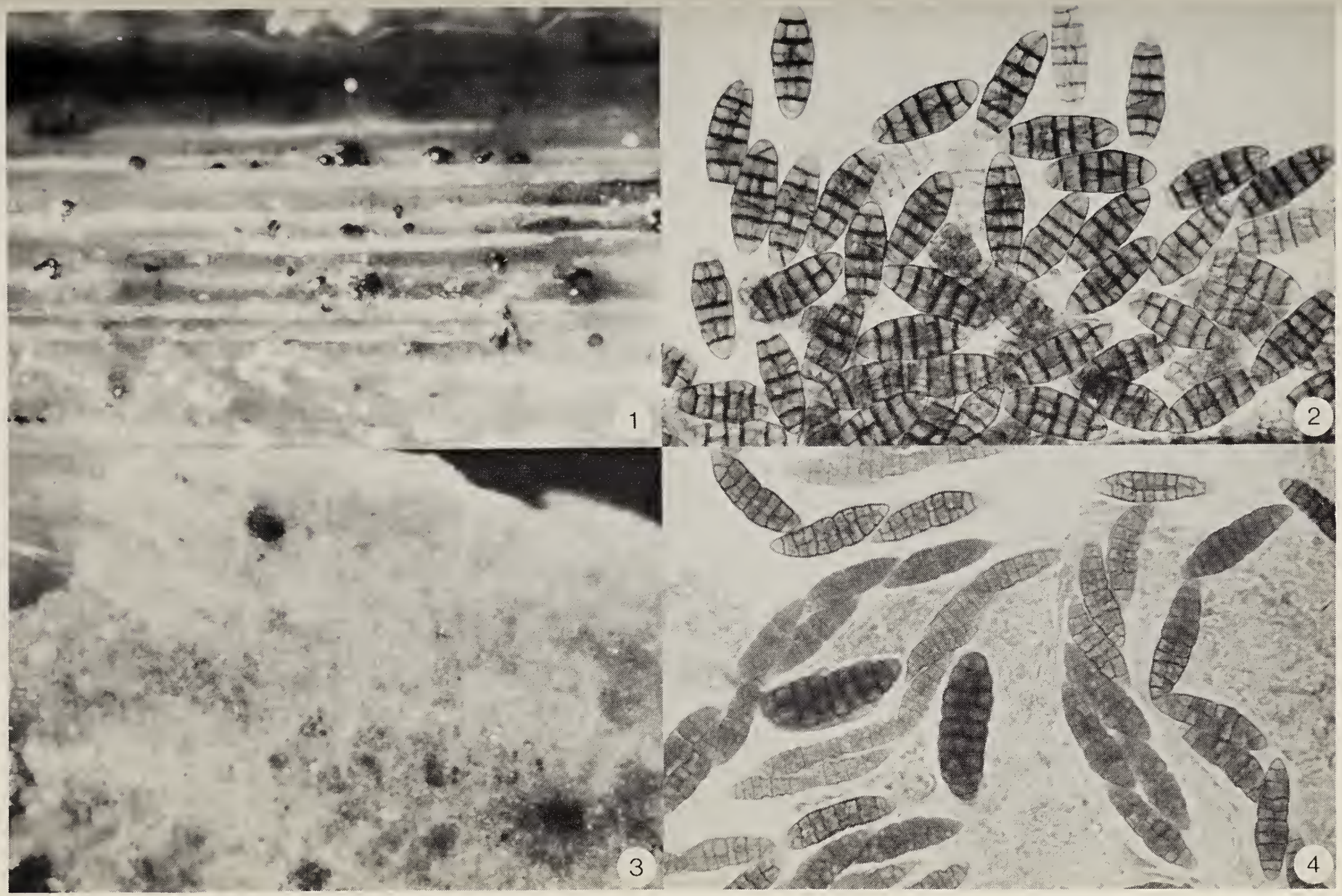
Ascocarps 350-370 μm in diameter, globose, immersed or slightly erumpent, black, solitary or gregarious. Pseudoparaphyses filiform. Asci 140-180 x 13-17 μm, eight-spored, cylindrical, apically rounded, bitunicate. Ascospores 24-28 x 9-11 μm, uniseriate, ellipsoidal, inequilateral, thick-walled, yellow-brown, muriform, usually 5 transverse septa, third cell wider than the others, occasionally 1 longitudinal septum in fourth cell. First report of this fungus outside the U.K. Collected at station 2. Voucher slide deposited in the Connell Memorial Herbarium (UNB). *P. spartinae* differs in several respects from *P. herbarm* which has been reported on a living marine angiosperm (Dickinson, 1965). *Pleospora herbarum* has longer and wider spores (26-50 x 10-20 μm), is mostly 7-septate and biserate (Wehmeyer, 1961).

Another marine *Pleospora*, *P. pelagica* Johnson (Fig. 3, 4) has been found on dead *Spartina* (Kohlmeyer & Kohlmeyer, 1979) and previously reported in New Brunswick on wood (Miller & Whitney, 1981a). The ascospores of *P. pelagica* are longer than *P. spartinae* (35-52 x 9.5-15 μm in the type description, Kohlmeyer & Kohlmeyer, 1979; 36-43(–45) x 10-13 μm, Miller & Whitney, (1981a) and also have 7-9 transverse septa and are biseriate. The collection of *P. pelagica* was marked by a deep red stain surrounding the ascocarps (Fig 3.) not seen in the collection of *P.*

Table IV Description of *Alternaria* isolates.

Species	Source	Conidia on SCZ[1]	Conidia on CZ[2]	Culture Colour
Alternaria alternata	damp plaster[3]	20-25 (-30) x 8-12 µm R[4]	20-25 x 8-12 µm R	black
A. alternata	wallpaper[3]	20-40 x 10-12 µm S[5]	20-32 x 10-12 µm slightly R	gray-black
A. maritima?	*Spartina* roots	20-40 (-60) x 10-12 µm R	25-40 x 10-18 µm sl. R	olive green
A. maritima?	seawater	25-30 (-45) x 10-15 µm R	25-30 (-40) x 8-15 µm R	gray-green
A. maritima?	seawater	23-30 (-40) x 19-12 µm sl. R	25-27 x 8-10 µm sl. R[6]	olive green
A. maritima?	*Fucus*	22-45 (-50) x 8-15 µm R	22-35 (-40) x 8-13 µm R	olive green
A. maritima?	*Ascophyllum*	22-45 (-48) x 9-13 µm R	22-40 x 8-14 µm R	olive green
		conidia		
Alternaria alternata type[7]		20-63 (x = 37) x 9-18 (x = 13) µm S and R		see text
A. maritima type[8]		30-50 x 12-18 µm R		olive green, brown
A. maritima[9]		16-71 x 8-15 µm		

NOTES:
1. seawater-Czapek's agar
2. Czapek's agar
3. Miller and Holland, 1981
4. rough conidia
5. smooth conidia
6. poor sporulation
7. Ellis, 1971
8. Sutherland, 1916
9. Johnson and Sparrow, 1961



1. Ascocarps of *Pleospora spartinae* on *Spartina alterniflora* (x ca. 20) stem
2. Ascospores of *P. spartinae* (x ca. 700)
3. Ascocarps (black) of *P. pelagica* on intertidal wood (x ca. 20)
4. Ascospores of *P. pelagica* (x ca. 600)

spartinae. Prof. J. Webster (Exeter) has observed *Pleospora* spp. causing a red stain in the substrate (pers. com., 1981). Wehmeyer (1961) lists *P. pelagica* as species *non vidi* although it was accepted by Kohlmeyer & Kohlmeyer (1979) and by Miller & Whitney (1981a).

Other marine species of *Pleospora* which have been reported from dead marine angiosperms include *P. gaudefroyi* Patouillard (ascospores 30-46.5 x 13.5-20.5 μm, with gelatinous appendages), *P. pelvetiae* Sutherland (ascospores 26.5-35 x 11.5-17 μm, with gelatinous sheath), *P. triglochinicola* Webster (ascospores 45-68 x 16.5-25 μm with a mucilaginous sheath) and *Pleospora* sp. 1 (ascospores 40-52 x 16-10 μm, with a gelatinous sheath) (Kohlmeyer & Kohlmeyer, 1979).

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SEEDBANKS IN SEVERAL RECENTLY CLEAR-CUT AND MATURE HARDWOOD FORESTS IN NOVA SCOTIA

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Forest floor organic layers from three 75-year-old hardwood stands were examined for the occurrence of early successional species in the seedbanks prior to disturbance. In addition, two 5-year-old hardwood clear-cuts were examined in order to compare the seedbanks of immature and mature stands. One clear-cut had a total number of germinants that was intermediate to those of the mature stands. The other clear-cut had a much larger seedbank. Species composition of the seedbanks varied considerably among the stands. However, each mature stand had several species in the seedbanks that were not present as adult plants e.g., *Aster* spp., *Rubus* spp., *Prunus pensylvanica*, and *Sambucus pubens*. *Prunus pensylvanica* was found to be a relatively minor component of the seedbanks, whereas *Rubus idaeus* was found to be relatively abundant in the seedbanks of the mature stands. Regeneration strategies are discussed for the more important species present in the seedbanks.

Les couches organiques du sol de trois associations de bois dur agées de 75 ans ont été examinées dans le but de détecter la présence, parmi l'ensemble des graines présentes des espèces appartenant aux premiers stades de succession et ce, avant perturbation. De plus, deux coupes claires de bois dur, agrées de 5 ans, ont été examinées dans le but de comparer l'ensemble des graines présentes dans des associations matures et immatures. Un coupe claire avait un nombre total de graines germées intermédiaire de ceux des associations matures, tandis que l'autre avait un nombre plus grand. La composition spécifique que l'ensemble des graines variait considérablement parmi les differentes associations. Cependant, chaque association mature possédait plusieurs espéces de graines qui n'étaient pas représentées parmi les plantes adultes e.g., *Aster* spp., *Rubus*, spp., *Prunus pennsylvanica*, et *Sambucus pubens*. Il a été noté que *Prunus pennsylvanica* représentait une composantes mineuse de l'ensemble des graines tandis que *Rubus idaeus* etait relativement abondant dans les associations matures. Les stratigées de régéneration sont discutées pour les espèces les plus abondamment représentées dans l'ensembles des graines.

Introduction

Succession in a forest is disrupted by major disturbances, such as harvesting or fire. The initial response of the vegetation includes a proliferation of ruderal plant species, usually mixed with some surviving later-successional species. For example, seedlings of some species that occurred prior to the disturbance appear with seedlings of species that are only associated with early series. These seedlings, along with vegetative survivors of the disturbance, serve to re-colonize the site.

Seedbanks, which have developed from the accumulation of viable seeds over the stand's history, are partially responsible for the regeneration by sexual propagules (Oostings & Humphreys 1940; Olmstead & Curtis 1947; Marks 1974; Johnson 1975; Marquis 1975; Moore & Wein 1977; Bormann & Likens 1979). Seed inputs leading to the development of these seedbanks occur from the following sources: (i) exogenous seed dispersed by wind and animals from surrounding sites, and (ii) endogenous seed produced *in situ* over the course of time. The longevity of seed viability varies among plant species which, in combination with annual seed production, will affect the contribution to the seedbank.

Grime (1979) divided the seedbank into two components: (i) transient-seed viability lasting for one year, and (ii) persistent-most seed remaining viable for more than one year. Livingston and Allessio (1968) found that most species exhibiting a

buried seed strategy were herbaceous. Although Harper (1977) stated that tree seeds were rarely present in seedbanks, Marks (1974) found pin cherry (*Prunus pensylvanica* L.) seeds to be an exception.

From a silvicultural point of view, the post-disturbance establishment of a vigorous and competitive plant community from the seedbank may be a problem, since the successful regeneration of desired tree species may be impeded by this vegetation (Olmstead & Curtis 1947; Graber & Thompson 1978). Ecologically, however, the rapid establishment of vegetation on a disturbed site may contribute to the recovery of site stability by minimizing soil erosion and nutrient loss (Marks 1974; Bormann & Likens 1979). For example, Bormann & Likens (1979) measured significant nutrient losses from a clear-felled watershed that had been subjected to three years of herbicide treatments to retard revegetation.

The purpose of this study is to investigate the size and species composition of the seedbanks of a hardwood forest in Nova Scotia. By identifying the relative proportion of early and late successional species in two age-classes of hardwood stands, it will be possible to determine whether ruderal species exist in the seedbanks of mature stands prior to disturbance. In addition, the regeneration strategies adopted by the more important species present will be discussed.

Study sites

The five stands used in this study were located in a hardwood forest in central Nova Scotia (44°55'N, 65°44'W) in an area mapped by Loucks (1962) within the Sugar maple-Hemlock-Pine Zone. The three mature stands originated approximately 75 years ago following a fire (Freedman *et al.*, 1981). Site A was dominated by sugar maple (*Acer saccharum* Marsh) and red maple (*A. rubrum* L.), with lesser amounts of yellow birch (*Betula allegheniensis* Britt.) and white birch (*B. papyrifera* Marsh) (Table I). The total stem density was 1835/ha, and the total basal area was 32.1 m^2/ha. Shrub density (i.e., < 5 cm diameter at breast height) was low in this stand, with only 300 stems/ha, mostly sugar maple.

Site B had 1580 trees/ha and a total basal area of 27.2 m^2/ha. It had an even distribution of hardwood species (Table I). Shrubs (total stem density of 2360/ha) consisted mostly of sugar maple, with smaller quantities of red maple and striped maple (*Acer pensylvanicum* L.) also present.

Site C consisted mainly of red maple and white birch (Table I). The total stem density was 1300 trees/ha, with a basal area of 18.9 m^2/ha. Shrubs were diverse and abundant (7320 stems/ha) with alder (*Alnus* app.), witherod (*Viburnum cassinoides* L.), red maple, and beech (*Fagus grandifolia* Ehrh.) being the most common.

The remaining two sites were clearcut 5 years previously and were dominated by (i) stump sprouts of hardwood trees and shrub species, and (ii) a dense ground vegetation consisting of a diverse mixture of ruderal plant species. The shrub-sized vegetation of Site D was mainly red maple and alder, with smaller quantities of beech and pin cherry. The total stem density was 23,600/ha. Red maple and white birch were most abundant in Site E, with lesser amounts of pin cherry, white ash (*Fraxinus americana* L.), sugar maple, and raspberries (*Rubus* spp.). Total shrub stem density was 36,800/ha.

Methods

In November, 1981, samples were collected from six 50 cm x 50 cm quadrats at each 75-year-old stand, and three quadrats in each 5-year-old stand. All organic forest floor material down to the mineral soil was collected and taken to the laboratory. Following 1 1/2 months of storage at below-freezing temperatures, each sample was mixed and spread to a depth of *ca.* 2 cm in plastic trays. These

Table 1 Density and dominance of tree species in the three uncut hardwood stands[1,2]. Values expressed as percentages.

Species	Stand A		Stand B		Stand C	
	Relative Density	Relative Dominance	Relative Density	Relative Dominance	Relative Density	Relative Dominance
Acer rubrum	37.9	41.8	26.9	32.4	48.8	45.4
Betula papyrifera	11.7	19.5	33.5	33.9	35.8	44.8
B. alleghaniensis	14.7	12.2	21.5	12.4	6.5	4.6
Picea rubens	0.5	0.1	2.2	4.1	0.8	0.1
Amelanchier spp.	a	a	a	a	0.4	0.3
Pinus strobus	a	a	a	a	6.1	3.8
Fagus grandifolia	2.2	0.5	1.0	0.5	0.8	0.3
Alnus spp.	a	a	a	a	0.4	0.1
Picea glauca	a	a	a	a	0.4	0.6
Acer saccharum	33.0	25.9	14.6	16.6	a	a
Acer pensylvanicum	a	a	0.3	0.1	a	a
Total	1835 trees/ha	32.09 m^2/ha	1580 trees/ha	27.21 m^2/ha	1300 trees/ha	18.86 m^2/ha

[1]a = absent from stand
[2]Data collected in five 20 m x 20 m plots per stand.

trays were kept in a greenhouse, where they received daily waterings and a 16h artificial light regime which supplemented the mid-winter natural sunlight. All seedlings in the trays were harvested after 75 d. Then the soils were mixed again and placed back in the greenhouse to extract more germinants. After a further 30 d, the germination trials were terminated. Since the soil samples were collected in November, both buried seed and the current season's input of viable seed would be included in the seedbank. The germinated seeds were allowed to develop to facilitate identification, which follows the nomenclature of Roland & Smith (1969).

Stand descriptions of the trees and shrubs found in the sites are summarized in Tables I and II. In addition, observations of the various ground species in each site were made, but these data are not presented here. However, seedlings that appeared in the soil samples which were present in the vegetation of the sites are marked in Table III.

Results and Discussion

Germinated seeds from the five sites represented at least 37 genera of vascular plants, with seedbank composition varying considerably among the sites (Table III). The major difference between the mature and clear-cut sites was the higher proportion of ground vegetation species (mainly herbs) found in the latter (78 and 75% of all species in the clear-cuts, compared with 61% in the mature stands). Much of the ground vegetation was comprised of early successional species having a ruderal life history strategy (Grime 1979). Their short life cycle and high seed output ensure their rapid establishment and early prominence in disturbed environments.

Total seed germination ranged from *ca.* 700 to 4750/m^2. The largest seedbank was found in the clear-cut Site D, but the other clear-cut had a seedbank that was intermediate in size to that of the three uncut stands (Table III). The difference between the two clear-cuts can be attributed to the large quantities of *Rumex acetosella* and unidentified grasses at Site D, which accounted for 84% of the total number of germinated seeds at that site.

Harper (1977) generalized that early successional species tend to make a greater contribution to seedbanks than late successional species. In the 5-year-old stands (Sites D and E) and one 75-year-old stand (Site A), herb species that we consider to be early successional in nature contributed a high proportion of the total number of germinants (96,87, and 69% respectively). On the other hand, these species only contributed 28 and 20% of the total number of germinants in the other two 75-year-old stands (Sites B and C), where tree seeds dominated the seedbanks (Table III).

White birch was the most abundant tree species in the seedbank of all sites, accounting for 98% of all tree seeds that germinated. Frank and Safford (1970) found that birch seed remained viable in the soil for two years. Thus, its contribution to the seedbank would be transient since the amount of viable white birch seed found in any year is dependent upon a constant production of seed from mature plants. The fugitive strategy, as exhibited for trees by white birch, is common among early successional species (Marks 1974; Grime 1979). The lower density of white birch seed in the clear-cuts (71 and 79 seeds/m^2) compared with the mature stands (290, and 486 seeds/m^2) may be due to the lack of mature trees in the 5-year-old stands. Thus, exogenous seed input from surrounding uncut stands is necessary to maintain white birch in the clear-cut seedbanks.

Early successional species that were present in the seedbank, but not in the established vegetation, totalled 5, 10, and 7 species for the mature sites A, B, and

Table II Relative Shrub Density (As Percentages)

Species	Site A	Site B	Site C	Site D	Site E
Fagus grandifolia	3.3	3.4	13.1	6.4	4.4
Acer rubrum	1.7	22.0	19.1	46.6	30.5
Fraxinus americana	a	1.7	a	0.7	10.3
Acer saccharum	72.0	35.6	0.5	0.8	8.5
Betula papyrifera	1.7	1.7	3.3	a	19.9
Acer pensylvanicum	1.7	15.2	a	a	3.0
Amelanchier spp.	a	a	2.7	0.8	0.6
Hammenalis virginiana	1.7	a	2.2	a	a
Rhododedron spp.	a	a	7.6	a	a
Viburnum cassinoides	a	a	21.9	a	1.1
Pinus strobus	a	a	1.6	a	a
Abies balsamea	a	a	0.5	1.0	a
Alnus spp.	a	a	25.1	40.7	a
Betula alleghaniensis	10.0	11.9	1.1	a	a
Picea rubens	8.3	8.5	1.1	0.3	a
Populus tremuloides	a	a	a	0.2	2.0
Prunus pensylvanica	a	a	a	2.2	10.5
Rubus allegheniensis	a	a	a	a	2.9
Rubus idaeus	a	a	a	0.2	4.9
Salix spp.	a	a	a	a	1.3
Total (stems/ha)	300	2360	7320	23600	36840

[1]Density of shrubs (DBH <5 cm) in the five stands studied.
[2]a = absent from stand.
[3]Data were collected using ten 5 m x 5 m plots per stand.

Table III Seedbank Germinants ($\bar{x} \pm$ S.E., Values In Seeds/m^2).

Species	Site A	Site B	Site C	Site D	Site E
TREES					
Acer pensylvanicum L.	0.8 ± 0.8(P)[1]	— (P)	—	—	— (P)
Acer rubrum L.	2.8 ± 0.8(P)	2.0 ± 1.2(P)	0.8 ± 0.8(P)	— (P)	1.2 ± 1.2(P)
Betula alleghaniensis Britt.	1.2 ± 1.2(P)	— (P)	—	1.2 ± 1.2	—
Betula papyrifera Marsh.	290.0 ± 80.8(P)	460.0 ± 48.4(P)	486.0 ± 90.4(P)	70.8 ± 44.8(P)	78.8 ± 18.0(P)
Populus tremuloides Michx.	—	—	—	—	1.2 ± 1.2
Prunus pensylvanica L.f.	—	2.0 ± 1.2	2.0 ± 2.0	2.8 ± 2.8(P)	— (P)
SHRUBS					
Ribes spp.	—	1.2 ± 1.2	—	—	—
Rubus hispidus L.	—	0.8 ± 0.8	5.2 ± 4.0	— (P)	— (P)
Rubus idaeus L.	45.2 ± 34.4	112.8 ± 46.0	29.2 ± 17.6	117.2 ± 30.0(P)	26.8 ± 24.8(P)
Sambucus pubens Michx.	0.8 ± 0.8	8.0 ± 5.2	16.8 ± 14.4	— (P)	— (P)
Vaccinium myrtilloides Michx.	1.2 ± 0.8(P)	31.2 ± 30.4(P)	22.8 ± 7.2(P)	2.8 ± 1.2(P)	9.2 ± 9.2(P)
Viburnum cassinoides L.	—	0.8 ± 0.8(P)	— (P)	— (P)	— (P)
GROUND VEGETATION					
Anaphalis margaritacea (L.) C.B. Clarke	2.0 ± 1.2	7.2 ± 2.0	—	2.8 ± 1.2(P)	37.2 ± 37.2(P)
Aralia nudicaulis L.	0.8 ± 0.8	— (P)	1.2 ± 1.2(P)	1.2 ± 1.2(P)	— (P)
Aralia racemosa L.	—	—	—	—	2.8 ± 2.8
Aralia hispida Vent.	—	—	—	4.0 ± 4.0	—
Aster spp.	2.0 ± 1.2	2.0 ± 0.8	0.8 ± 0.8	70.8 ± 68.8(P)	53.2 ± 27.6(P)
Carex spp.	566.8 ± 449.6	89.2 ± 30.0	86.0 ± 38.8	273.2 ± 271.2(P)	21.2 ± 21.2(P)
Cornus canadensis L.	— (P)	— (P)	— (P)	4.0 ± 4.0(P)	1.2 ± 1.2(P)
Corydalis sempervirens (L.) Bernh.	—	—	—	—	1.2 ± 1.2
Epilobium angustifolium L.	—	6.8 ± 4.4	—	1.2 ± 1.2(P)	17.2 ± 17.2(P)
Fragaria virginiana Duchesne	—	—	—	—	100.0 ± 79.2(P)
Gramineae spp.	58.0 ± 54.0(P)	37.2 ± 18.0(P)	0.8 ± 0.8(P)	1838.8 ± 919.6(P)	380.0 ± 183.6(P)
Hieracium spp.	1.2 ± 0.8(P)	0.8 ± 0.8	—	1.2 ± 1.2(P)	45.2 ± 30.8(P)
Linnaea borealis L., var. *americana* (Forbes) Rehd.	—	—	—	4.0 ± 4.0	—
Lycopodium spp.	— (P)	0.8 ± 0.4(P)	— (P)	—	—

Maianthemum canadense Desf.	7.2 ± 4.0(P)	13.2 ± 6.4(P)	— (P)	21.2 ± 11.6(P)	22.8 ± 22.8(P)
Oxalis montana Raf.	34.0 ± 34.0(P)	1.2 ± 1.2	0.8 ± 0.8	—	—
Potentilla spp.	—	—	3.2 ± 1.6	—	—
Prenanthes spp.	— (P)	—	—	5.2 ± 5.2	—
Rumex Acetosella L.	—	—	—	2133.2 ± 1951.2(P)	1.2 ± 1.2(P)
Solidago rugosa Ait.	— (P)	17.2 ± 4.4(P)	18.8 ± 13.2(P)	161.2 ± 50.8(P)	76.0 ± 24.4(P)
Solidago spp.	—	0.8 ± 0.8	—	12.0 ± 12.0(P)	— (P)
Sonchus spp.	3.2 ± 3.2	4.0 ± 1.6	—	2.8 ± 1.2	—
Trientalis borealis Raf.	14.0 ± 9.2(P)	— (P)	12.8 ± 4.0(P)	1.2 ± 1.2	—
Veronica officinalis L.	—	—	4.8 ± 3.2	—	—
Viola spp.	64.8 ± 30.0(P)	59.2 ± 30.0(P)	13.2 ± 9.6(P)	16.0 ± 14.0(P)	14.8 ± 9.2(P)
Unknown	—	0.8 ± 0.4	0.8 ± 0.8	—	2.8 ± 1.2
TOTAL GERMINANTS	1096.0 ± 376.8	859.2 ± 127.6	706.0 ± 148.0	4748.8 ± 2230.0	894.0 ± 74.0
TOTAL TREE	294.8 ± 80.4	464.0 ± 48.4	488.8 ± 90.8	74.8 ± 48.8	81.2 ± 18.8
TOTAL SHRUB	47.2 ± 34.8	154.8 ± 62.4	74.0 ± 23.6	120.0 ± 30.4	36.0 ± 34.0
TOTAL GROUND VEGETATION	754.0 ± 422.0	240.4 ± 69.2	143.2 ± 63.2	4554.0 ± 2030.4	776.8 ± 75.2
TOTAL SPECIES	18	23	18	23	20
TOTAL TREES	4	3	3	3	3
TOTAL SHRUBS	3	6	4	2	2
TOTAL GROUND VEGETATION	11	14	11	18	15

[1]p = present in site vegetation.

C, respectively. These accounted for 28, 43, and 39% of the total number of species and 7, 16, and 9% of the total number of germinants in these respective sites. Harper (1977) predicted a difference between seedbank composition and the composition of the vegetation of the site. A life history that includes the buried seed and/or fugitive strategy helps promote this difference (Marks 1974; Grime 1979). In this study, examples of the buried seed strategy include the raspberries, pin cherry, and elders (*Sambucus* spp.), with asters (*Aster* spp.) exemplifying the fugitive strategy.

The asters and goldenrods (*Solidago* spp.), although not present on site, contributed 2.0 (Site A), 20.0 (Site B), and 19.6 (Site C) seeds/m^2 to the seedbanks of the mature stands. Many Asteraceae have a pappus and light seed which increase their dispersal range. However, in these cases, mobility has been favored over seed longevity (Harper 1977), which means that the contribution to the seedbank will be relatively transient. Therefore, species exhibiting the wind-dispersed fugitive strategy such as many Asteraceae, must rely upon large seed outputs in order to ensure successful establishment on disturbed sites within their dispersal range (Grime 1979).

Pin cherry is a well-documented example of a tree species that exhibits a buried seed strategy (Marks 1974). In a study in Pennsylvania, Marquis (1975) found 490 pin cherry seeds/m^2 in a stand, even though the species no longer occurred as mature trees. He suggested that the number of viable pin cherry seeds decreased as the time since pin cherry existed in the overstory increased. Marquis (1975) found that a sharp decrease in viability would be experienced once stand age increased beyond 70 years. In our study, two 75-year-old stands each had only 2 viable pin cherry seeds/m^2 and one 5-year-old site had 3 seeds/m^2. The values for the 75-year-old stands were lower than those found in other studies in northern hardwood stands (Marks 1974; Marquis 1975; Graber & Thompson 1978), although a similar value for a 5-year-old stand was reported by Graber and Thompson (1978). Lees (unpub. data 1980) also found pin cherry to be a minor component in the seedbanks of other hardwood stands in this area.

The low values for pin cherry may be related to the history of disturbance in the area. Mark's (1974) study of the life cycle of pin cherry showed that frequent disturbances were needed to promote a high density and, thus build large seedbanks. With few disturbances, the number of viable seeds decrease and avian dispersal of fruit becomes more important (Marks 1974). In the area we studied, disturbances have been infrequent, with harvesting only becoming important within the last decade, following the construction of a hardwood fibreboard mill nearby. Historically, fire would have been the major mode of disturbance. Cann *et al.*, (1965) stated that past fires were very intense, and that they destroyed much of the soil organic matter. This would also have destroyed most of the seedbank since many studies have shown that organic horizons contain many more seeds than the mineral soil (Leavitt 1963; Kellman 1970; Moore & Wein 1977; Graber & Thompson 1978).

In northern hardwoods, *Rubus* spp. will commonly dominate sites for the first few years following disturbances (Olmstead & Curtis 1947; Marks 1974; Moore & Wein 1977; Graber & Thompson 1978; Bormann & Likens 1979). We found *Rubus idaeus* to be abundant in the seedbanks of all sites. The site age classes did not exhibit any differences, with 117 and 27 seeds/m^2 in the 5-year-old sites, compared with 45, 113, and 29 viable seeds/m^2 in the mature stands. The high density in the uncut stands may be attributed to the ability of *Rubus* to persist for long periods in the seedbank (Graber & Thompson 1978), as well as to dispersal by birds and mammals (Olmstead & Curtis 1947; Martin *et al.*, 1951; Graber & Thompson 1978).

For example, Graber and Thompson (1978) estimated an annual deposition rate of *ca.* 0.7 *Rubus* seeds/m^2 in a study in New Hampshire. They also calculated that *Rubus* seeds remained viable in the soil for 50-100 years.

Although mature plants were not present in the uncut stands, *Sambucus pubens* was found in the seedbanks at a relatively high density, with 0.8, 8.0, and 16.8 viable seeds/m^2. *Sambucus* fruits are a preferred food for some birds, and these may have been important as agents of seed dispersal from nearby younger stands (Olmstead & Curtis 1947; Graber & Thompson 1978). *Sambucus* has been estimated to remain viable in the soil for up to 10-20 years (Graber & Thompson 1978).

In summary, the three mature stands had seedbanks similar in size to 5-year-old clear-cut (Site E). The other clear-cut had a much larger seedbank. In the seedbanks of the mature stands, early successional species were found in association with later successional species. Since some species were not present as mature plants, the presence of these early successional species in the seedbanks of the mature stands suggest their existence prior to disturbance. Some of the ruderal species are very persistent in the seedbank (e.g., *Prunus pensylvanica),* while others (e.g., *Betula,* Asteraceae) may be relatively ephemeral due to differences in seed longevity.

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AN APPARENT ABSENCE OF HETEROSIS IN HYBRIDS OF GRACILARIA TIKVAHIAE (RHODOPHYCEAE)[1]

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Inbred diploid tetrasporophytes from three different populations of *Gracilaria tikvahiae* were compared with F_1 hybrids in a preliminary attempt to detect heterosis. Growth rates of sporelings and of mature fronds were compared, as were some frond characteristics such as regeneration ability and dry weight. No heterosis was observed for any of the characteristics.

Au cours d'une expérience préliminaire visant à détecter les effets de l'hétérosis, des tétrasporophytes diploides, consanguins, provenant de trois populations différentes de *Gracilaria tikvahiae* furent comparés avec des hybrids F_1. Les taux de croissance des spores germées et des frondes matures ainsi que d'autres caractéristiques des frondes telles la capacité de régénération et le poid sec furent comparées. Les effets de l'hétérosis ne furent détectés pour aucune des caractéristiques étudiées.

Introduction

The term "heterosis" was coined to describe the increased vigor of hybrids over that of their parents (Shull 1911), a phenomenon of great importance in plant and animal improvement. It is, in general terms, the phenotypic expression of gene interactions in hybrids and is always associated with genetic heterozygosity. Thus, it is reduced by inbreeding and restored by hybridization.

In plants, the study of heterosis has been limited, for the most part, to diploid and polyploid angiospermic crop plants. Such research has been rare in lower plant groups, including the algae, some of which are important marine crops. For algal taxa where cultivated fronds are monoploid, such as *Porphyra,* heterosis would have no direct usefulness, although it might have some limited application in improving the growth of the diploid sporophytic phase which is used as spore-stock for generating the harvested haploid phase. Heterosis is potentially a much more important breeding consideration for taxa such as *Laminaria,* which the large diploid sporophytic fronds are cultivated; however, this remains to be demonstrated. Chinese workers have shown that some frond characteristics have strong additive genetic componenets (Fang et al. 1965; Anonymous 1976) but their experiments were not designed to examine heterosis. Chapman and Doyle (1979), on the other hand, found little or no additive genetic component in the transmission of genes for alginate content. Until more data become available, the role of heterosis in all diploid algae remains unknown.

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There is an additional consideration for species such as *Gracilaria tikvahiae* which alternate between isomorphic hapliod and diploid plants growing in the same habitat. For such species, haploid and diploid plants are potentially in direct competition with each other. This situation is very different from that of angiosperms and of algae with heteromorphic life histories where the haploid phase has a different growth strategy and thus does not, or is less likely to, face competition from the diploid phase. It is fair to question whether heterotic gene interactions should be expected in species with isomorphic phases, as heterosis might confer an advantage to diploids that would be to the detriment of the haploid plants and of the smooth functioning of the sexual life cycle.

Recently we decided to determine if any heterosis could be detected in hybrids of *G. tikvahiae* constructed from a limited number of lines that were sufficiently inbred to make the test feasible. The expression of heterosis was sought in the growth rate of sporelings, the growth rate of mature plants, regeneration ability and two other frond characteristics. An absence of any significant heterosis in the hybrids is reported here.

Materials and Methods

Inbred Lines and Hybrids

Partially inbred lines were developed from plants collected from three different local populations of *G. tikvahiae* McLachlan (McLachlan 1979). The collecting sites were: Barrachois Harbour, Colchester Co., N.S.; Pomquet Harbour, Antigonish Co., N.S.; and Malpeque Bay near Lennox Island, P.E.I. Inbred lines were designated as "Barrachois" (B), "Pomquet" (P) and "Lennox Island" (LI). To effect the inbreeding, each generation was initiated from a single diploid tetrasporophyte. For "Barrachois", inbred generation I_5 was attained, for "Pomquet" I_4, and for "Lennox Island" I_6.

The inbred lines above were used to construct age-matched families of inbred and hybrid plants. Families of inbred diploid sporelings were obtained for each of the lines by crossing 3 females with 3 males. More than a single mating pair was used in order to permit a broader sampling of the various genomes. Hybrid families were established at the same time by crossing: 3 Lennox Island females with 3 Barrachois males, 3 Pomquet females with 3 Barrachois males, and 3 Pomquet females with 3 Lennox Island males. The plants used to construct the hybrids were clones taken from the plants used to establish the inbred families. The sporelings obtained from all crosses were maintained under low light for 8 weeks before they were used, at which time they were all approximately 5 mm long.

Sporeling Growth Comparisons

For the Lennox Island and Barrachois lines, growth rate measurements were made on 30 randomly selected sporelings taken from the inbred sporeling families. For the (LI x B) F_1 hybrid sporelings, these measurements were made on 90 plants. Because the Pomquet line had only attained the I_4 generation, it and its hybrids were examined less critically. For each of: Pomquet inbred, the (P X LI) F_1 hybrid, and the (P X B) F_1 hybrid, growth rate measurements were made on 10 sporelings. Growth comparisons were made over a 4-week interval in a controlled temperature room at 20 C. Illumination was from 40W, cool-white, fluorescent lamps at a quantum irradiance of approximately 35 $\mu E\ m^{-2}s^{-1}$ with a 12 h light period. The growth medium was SWM-3 without soil or liver extract (McLachlan 1973) and it was replaced weekly. The plants were photographed on a photocopy machine at the beginning and end of the growth period. Plants were centered on the machine to avoid distortions that may occur at the edges. Lengths were measured from the

photocopies to obtain specific growth rates as $\ln (L_t/L_o)/t$ where L_o = initial length, L_t = final length and t = the duration of the growth interval in days.

Growth Comparisons for Mature Plants

The growth rate of mature inbred and F_1 hybrid tetrasporophytes was further compared in 10 l tanks of flowing seawater in a greenhouse after allowing at least 2 weeks for the laboratory-grown plants to acclimate to the greenhouse conditions. Due to space limitations it was not possible to grow, as large mature plants, all of the sporelings studied in laboratory culture. Accordingly, the numbers were reduced as follows: Barrachois and Lennox Island inbred lines, 27 plants each, split into three replications of 9 plants; the (LI X B) F_1 hybrid, 36 plants split into 4 replications of 9 plants; Pomquet inbred, the (P X L1) F_1 hybrid, and the (P X B) F_1 hybrid, 10 plants each, as before for sporelings.

The plants were grown for 4 weeks at 20 C under ambient light conditions with nitrogen and phosphate fertilizer added twice weekly so as to reach initial concentrations of 900 μM NO_3– and 90 μM $PO^3{}_4$–. Flushing rate was 5-8 volumes per day. Fragmentation of mature thalli made it impossible to weight individual plants and thus only one growth rate determination could be made for each replicate of 9 plants. In the Pomquet series, where there were unreplicated sets of 10 plants, only a single determination was possible for each set, and one of these, (P X B) F_1 hybrid, was not obtained as the plants became badly fouled by epiphytes. Plants in the Pomquet series were grown in a separate growth trial a few weeks after the others. Results are expressed as specific growth rates based on weight, as $\ln (W_t/W_o)/t$ where W_o = inital weight, W_t = final weight and t = the growth interval in days.

Other Comparisons

Regeneration ability was determined after the sporeling growth measurements, just before the plants were transferred to the greenhouse at the Atlantic Research Laboratory's Seaweed Culture Station. To do this, 5 mm sections of frond were excised from the main axis of each frond 1 cm below the apex. These excised portions were cultured for 4 weeks and the number of regenerated apices was counted, and expressed as the mean number per excised section. After the plants had grown at the Seaweed Culture Station, plant stoutness was measured (= the sum of thickness + width of fronds), and the % dry weight and ash-free dry weight were determined.

Results and Discussion

No evidence for heterosis was obtained from any of the variables measured. Sporeling growth rates for the hybrids did not significantly exceed those for the inbred lines (Table 1). In two comparisons the F_1 hybrids were intermediate to the inbred families and in the third, the very small increase of the (LI X B) hybrid over the best parental line was not significant ($t = 0.075$, $p \geq 0.9$; Table I). Thus for these combinations, there was no exploitable heterosis in the growth of sporelings. Similarly there was no heterosis in the growth of mature plants. In the two sets for which data were obtained, growth of the F_1 hybrids was intermediate to that of the inbred families (Table I).

The inbred lines differed in their regeneration ability with Lennox Island plants forming about 4 times as many new apices as Barrachois plants. Again the F_1 hybrid was intermediate (Table II). For this character, Pomquet and Lennox Island lines were similar with the F_1 hybrid not significantly better than the best parental line ($t = 0.175$, $p \geq 0.8$). Likewise, no heterosis was observed for the other three

Table I Growth rates of inbred and hybrid plants

Genotype	Sporeling Growth Rate $\ln (L_t/L_o)/t$ $n \geq 10$	Mature Plant Growth Rate $\ln (W_t/W_t$ $N = 3$
LI X LI	0.118 ± .003	0.066 ± .009
LI X B	0.120 ± .001	0.063 ± .005
B X B	0.117 ± .002	0.059 ± .002
LI X LI	(0.118 ± .003)[1]	0.046[2]
LI X P	0.116 ± .002	0.051[2]
P X P	0.105 ± .002	0.057[2]
B X B	(0.117 ± .002)	———
B X P	0.112 ± .002	———
P X P	(0.105 ± .002)	———

All values are $\bar{x}$ ±S.D.
[1]values in parentheses are repeated for ease of comparison.
[2]These plants were grown unreplicated in a separate experiment.

Table II Characterization of inbred and hybrid plants*

Genotype	Stoutness of the frond (mm) n 10	Regeneration section^{-1} n≥30	% dry wt n = 3	% ash free dry wt n = 3
LI X LI(I_7)	2.84±0.01	3.38± 0.21	9.45	48.8
LB X B (F_1)	2.97± 0.04	1.41± 0.13	9.07	46.8
B X B(I_6)	3.09± 0.07	0.86± 0.20	8.93	46.0
LI X LI(I_7)	3.93±0.04[3]	(3.38± 0.21)	10.40[2]	53.5[2]
LI X P(F_1)	4.26±0.04[3]	3.50± 0.43[1]	9.60[2]	48.9[2]
P X P(I_5)	5.02±0.03[3]	2.80± 0.20[1]	9.69[2]	48.4[2]

Values are reported as $\bar{x}$±S.E. for first two columns. Values in the last two columns are single values or the average of 3 determinations.

*Results are comparable within each subset, but not between subsets, as the plants were grown in two different trials.

[1]n = 10
[2]n = 1
[3]Although only 10 plants were present originally, more thalli were measured at the end of the growth period due to fragmentation.

frond characteristics measured, the hybrids being intermediate in all cases (Table II).

The results of this preliminary study suggest that heterosis is not an important genetic component for the growth of tetrasporophytes of *G. tikvahiae*. The comparisons made for Barrachois, Lennox Island and their F_1 hybrid are reasonably complete and yield no evidence for hybrid vigor. It remains possible that by chance, this is a non-heterotic combination in a system where heterosis plays an important role; however, the similarly negative results obtained from the other two combinations suggests that an absence of heterosis may be the general situation.

The results perhaps complement observations that there does not appear to be any growth superiority of diploid tetrasporophytes over haploid gametophytes

(Edelstein 1977). With the bold assumptions that the same genes control growth of haploids and diploids and that growth reductions caused by reproductive effort are approximately equal for both phases, then the absence of a strong diploid superiority can also be taken to indicate that heterosis is not a large factor in the growth of *Gracilaria tikvahiae*. It appears from data available thus far that breeding approaches based on maximizing hybrid vigor will have no application in this alga.

Failure to demonstrate heterosis in these tests did not result from an absence of heterozygosity in the hybrids. The inbred lines differed from each other in morphological characteristics and were derived from different populations. It is possible that the "inbred" lines retained enough heterozygosity to express a high degree of hybrid vigor and that failure to see heterosis was due to insufficient inbreeding of the control lines; however, this seems unlikely as five or six generations is a significant amount of inbreeding.

It is likely that the traits measured here are determined by additive factors, but this remains to be proven in properly designed quantitative genetic experiments. Some single gene differences can have large effects on plant morphology and growth rate (Patwary & van der Meer 1982), and polymorphism for such genes may also contribute to the total variability observed.

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BAY OF FUNDY BIBLIOGRAPHY: SUPPLEMENT III

The references included herein supplement the recent extensive bibliography, **Moyse, C.M.** 1978. Bay of Fundy Environmental and Tidal Power Bibliography. Fish. Mar. Serv. Tech. Rep. No. 822, and its two supplements; Proc. N.S. Inst. Sci. (1979), 29: 313-314 and Proc. N.S. Inst. Sci. (1981), 31: 181-185. The present citations were either omitted through oversight or have been published subsequently.

Any references or omissions for inclusion in future supplements should be sent to: **P.J. CRANFORD, Marine Ecology Laboratory, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, N.S. B2Y 4A2.** All citations received are included, even internal reports that can be difficult to obtain.

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BRIEF COMMUNICATION

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CANADA GOOSE NUMBERS, DAILY MOVEMENTS AND FORAGING PATTERNS ON PRINCE EDWARD ISLAND

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Numbers, daily movements and foraging patterns of Canada geese (*Branta canadensis*) on 2 watersheds in Prince Edward Island were examined in 1974-1975. In spring, geese arrived before traditional feeding areas were free of ice, and remained for 2 months reaching a maximum of 6,200 birds. Regular daily movements from resting sites to cultivated fields where the birds remained for 6-12 hours were noted. As the estuaries became free of snow and ice, geese spent more time loafing and feeding in salt marshes. In autumn, geese were present for four months with peak numbers less than 40% of those recorded in spring. In fall, geese restricted their foraging to large fields, until extensive autumn cultivation forced them to feed mainly on tidal flats. Resting areas least accessible to hunters were utilized most commonly.

En 1974 et 1975, les déplacements quotidiens et les patrons de recherche de la nourriture de l'Oie du Canada (*Branta canadensis*) furent examinés dans deux bassins hydrographiques de l'Ile-du-Prince-Edouard. Au printemps, les oies arrivèrent avant la disparition de la glace des aires traditionnelles de nutrition. Elles séjournèrent pendant deux (2) mois et atteignirent un nombre de 6,200. Les déplacements reguliers des oiseau depuis les sites de repos vers les champs cultives, ou les oiseaux séjournent pendant 6 à 12 heures, furent notés quotidiennenment. Après la disparition de la glace et de la neige des estuaries, les oies passerent plus de temps dans les marois salants a flâner et a se nourris. En automne, les oies furent présentes pendant quatre (4) mois mais leur nombre maximum representait moins de 40% de celui en régistré au printemps. A l'automne, les oies ont recherché leur nourriture dans les grands champs jusqu'a ce que les travaux de culture de grande envergure les forcent à se nourrir principalement dans les plaines intertidales. Les aires de repos les moins accessibles aux chasseurs étaient utilisées plus courament.

Introduction

In the North Atlantic Flyway, Canada geese (*Branta canadensis*) winter on ice-free coasts of eastern Canada and northeastern United States, migrate through the Maritime Provinces and breed primarily in Newfoundland, Labrador and Quebec (Bellrose 1976). Prior to arrival at the breeding grounds, Canada geese undergo a hyperphagic phase and body weights increase by about one-third of winter weight (McLandress and Raveling 1981a). In giant Canada geese (*B.c. maxima*), these energetic reserves were obtained on the wintering area (McLandress and Raveling, 1981b), but for interior Canada geese (*B.c. interior*), birds were heaviest on a migratory stopover area, and Hanson (1962) suspected that geese in this population attained their peak body weight during spring migration. Birds probably leave wintering areas in varying body conditions depending on the severity of weather, and during a late spring breakup, geese may rely on foraging areas enroute to accumulate the reserves necessary for breeding. Despite their potential importance in the life cycle, migratory stopover areas for Canada geese have received remarkably little attention, especially the Atlantic Flyway population.

The expansive shallow bays and estuarine salt marshes of Prince Edward Island traditionally have been attractive to migrating Canada geese in spring and fall. During the past 2 decades, the number of migrant geese has increased and they have altered their feeding habits, choosing large exposed agricultural fields in preference to marshes and tidal flats. Implications of these changes have been discussed by Reed (1970). To begin documentation on changing patterns of use by Canada geese of migratory stopover areas, we provide in this paper data on numbers of geese and their daily activity patterns in spring and autumn on a 20,000 ha area of southwestern Prince Edward Island during 1974 and 1975.

Study Area

The study area, located on the southern coast of Prince Edward Island, included sections of the Dunk and Wilmot Rivers and Salutation Cove, plus surrounding lands almost entirely devoted to agriculture. A narrow band of fresh water marsh occurred along both rivers and gradually broadened downstream into salt marsh and extensive tidal flats (Fig. 1). Salt marsh vegetation was composed primarily of *Spartina patens* with patches of *Scirpus maritimus*, *Carex paleacea* and *Spartina pectinata*. A narrow band of *Spartina alterniflora* and *Solidago sempervirens* grew along the edge of the water. Due to heavy siltation, there was very little submergent vegetation in the Dunk and Wilmot estuaries. *Ulva lactuca*, *Zostera marina* and *Enteromorpha* sp. were the most abundant submergents available in Salutation Cove.

Major agricultural crops grown in the study area were potatoes (*Solanum tuberosum*), oats (*Avena sativa*) with barley (*Hordeum vulgare*) and clover (*Trifolium spp.*) with small acreages of peas (Pisum sativum) and corn (*Zea mays*). Most fields were relatively large (40-100 ha) separated by sparse hedgerows and interspersed with small wood lots. A network of roads provided easy access for field observations.

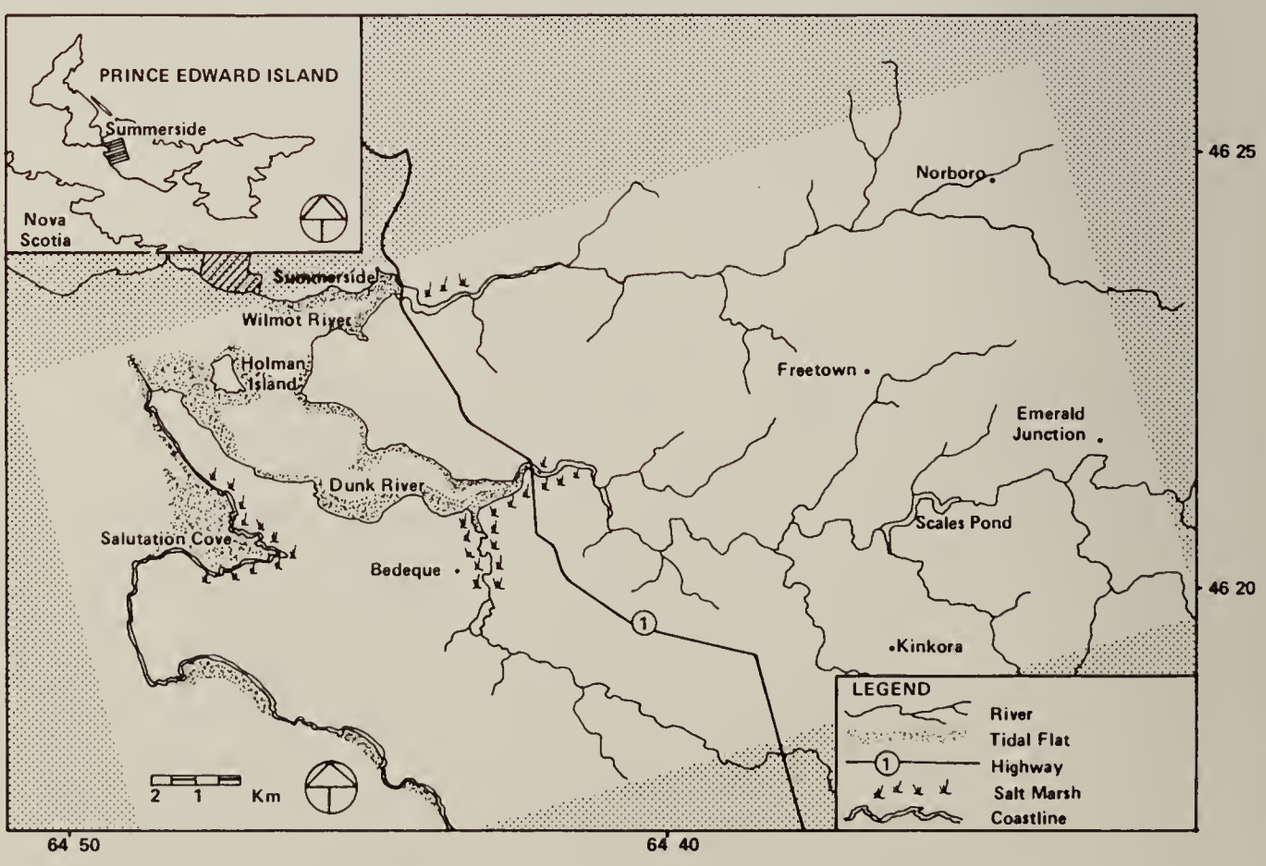

Fig 1 Study Area, Prince Edward Island, Canada.

Methods

In spring, at least 1 complete census was obtained for each 10-day period that geese were present during both years. Data on time, numbers, and direction of geese leaving and returning to resting sites were obtained by positioning 2-4 observers on high ground viewpoints. In 1975, to supplement spring ground observations, an aerial survey was conducted at 10-day intervals. We flew over the study area in a Cessna 172 at 200 m following a grid pattern. As well, geese were observed while they fed and loafed, and flock size, movements and habitat were recorded.

During autumn of both years, regular ground observations were made, and aerial surveys were conducted twice weekly.

Weather information was obtained from the Canadian Forces Weather Office, Summerside, 10 km west of the study area.

Results

Spring Numbers

March was relatively mild in 1974 with at least 0.25 cm of snow falling on 10 different days but usually only a trace remained on the ground. In March 1975 over 0.25 cm of snow fell on 16 days and the cumulative depth on the ground varied from 38-104 cm.

In 1974, geese arrived on the study area in early March and numbers increased rapidly to approximately 1,800 by mid-March (Fig. 2A). By mid-April, 5,760 geese were observed and a month later all had departed.

Owing to greater snow depth and harsher weather conditions, numbers of geese increased later in 1975, but as in 1974, a peak in numbers occurred by mid-April (Fig. 2B). Inclement weather in late April prevented an aerial census. Since ground counts generally were 20-30% lower than aerial counts, the decline during late April indicated in Fig. 2B may not have occurred. Numbers of geese using the area in spring may be increasing. On 21 April 1977, at peak spring numbers, an aerial census showed 8,300 birds, approximately 2,100 more than were observed at the peak 2 years earlier.

Spring Movements and Foraging Patterns

When geese arrived in early March, they roosted in the Dunk River estuary, Wilmot River (upstream from Route 1) and Salutation Cove (Fig. 1). Numbers in these sites were variable and occasionally almost all geese would concentrate in 1 of these areas. The Dunk River estuary was the largest resting site, usually accommodating over 65% of the migrants. Salutation Cove was used extensively after spring cultivation was well underway.

For the first 2 weeks after they arrived, geese remained at the resting sites from 1-4 hours after sunrise. By the end of March, geese began calling just after dawn as they concentrated near the center of their roost. The first geese left the site shortly after sunrise, and within 5-10 minutes groups of 2 to 300 were departing rapidly. Although suitable fields were available to the east, south and north, most geese on any particular day flew in 1 direction. As noted by Raveling (1969), the direction of initial take-off from rest sites was determined by wind but this did not influence the predominant direction flown to fields. Mean time required for all geese to leave the resting site was approximately 1.5 hours in both years.

For the first half of the stopover period, geese spent 6-12 hours away from the roost. Generally, a flock moved at least once to another field in the morning and sometimes also in the afternoon. While in fields, they frequently were observed loafing. In late April and early May, after many fields had been cultivated, geese re-

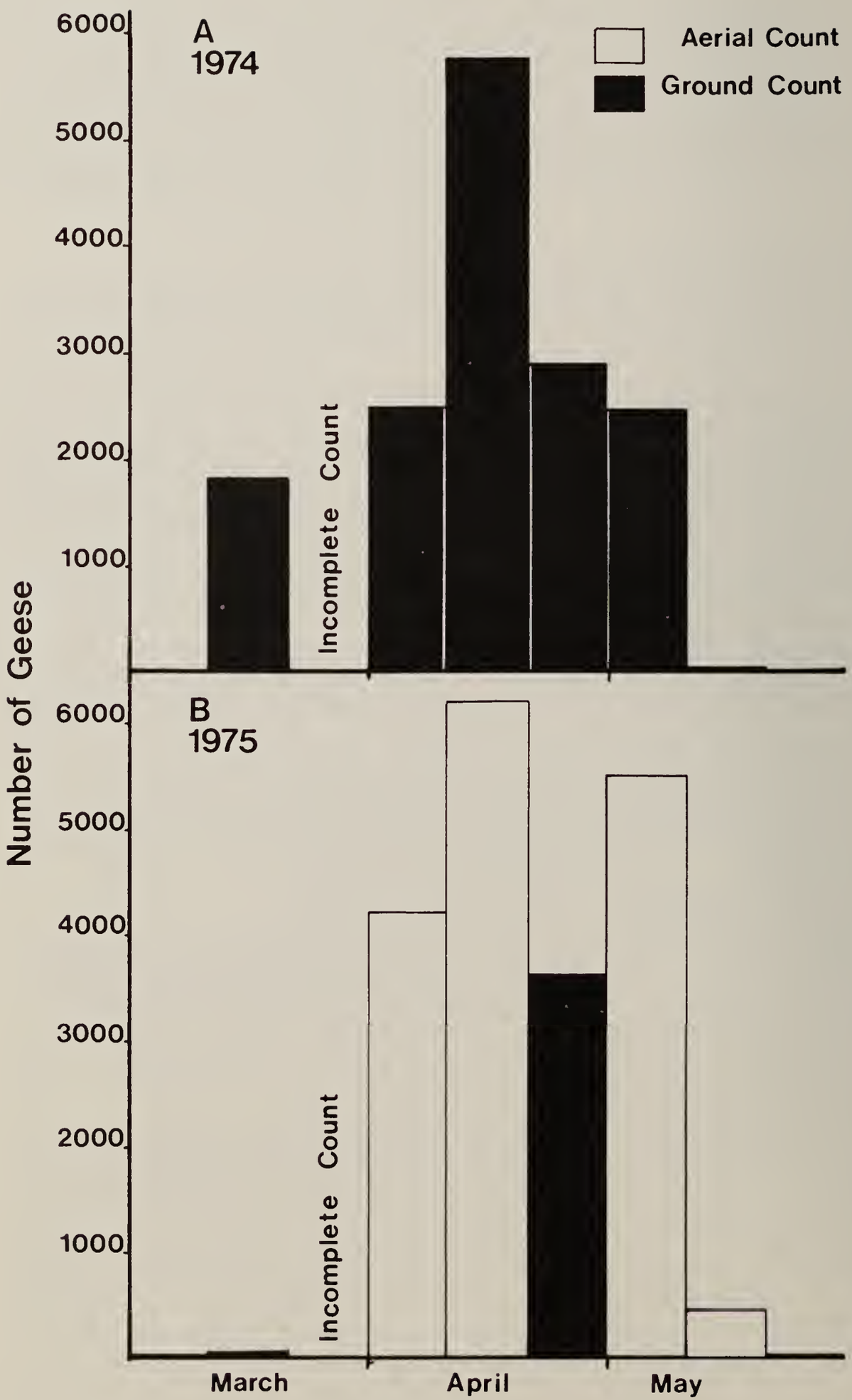

Fig 2 Maximum number of Canada geese observed during 10 day periods in spring on southwestern Prince Edward Island, 1974-1975.

turned by midmorning to loaf and feed on salt marshes where some remained for the rest of the day.

Fields available for foraging varied with crop rotation, snow conditions, and extent of cultivation the previous fall. Early in 1974, grain stubble near resting sites was used extensively, but as these food resources were depleted, geese moved further inland. Most observations of foraging geese occurred in grain stubble but potato and pea fields were also utilized. Deep snow cover during March 1975 caused problems for foraging geese; snow buried grain stubble and birds were obliged to feed on partially exposed potato fields. On 16 April 1974 and 14 April 1975, geese were observed grazing on salt marshes for the first time. Later in the season much time was spent feeding and loafing in salt marshes.

Flock size in fields varied from 4 birds to as many as 4,000; groups of 1,000-2,500 foraging geese were common.

Autumn Numbers

In 1974, only 32 geese were observed on the study area on 7 October, the opening day of the hunting season. Numbers built to a peak of 2,050 in late October and by mid-December most geese had left (Fig. 3A). In 1975, geese were seen first on 25 August, and 291 were present on the study area when the hunting season opened. A peak in numbers was not reached until the third week of November when 2,400 geese were present (Fig. 3B). In autumn, peak numbers of geese observed on the study area were less than 40% of spring numbers.

Autumn Movements and Foraging Patterns

In autumn, movements and feeding patterns were determined by hunting pressure, weather and agricultural activities. There was no evidence of a regular daily movement from resting sites to fields (≈ 40 ha) in autumn, and as in spring, they preferred grain stubble but also utilized pea and corn fields. Geese were not observed feeding in potato fields in fall.

Geese spent more time loafing and feeding in areas relatively inaccessible to hunters such as Salutation Cove and south of Holman Island. In 1975 favorable weather permitted early harvest of crops. Autumn cultivation was extensive and little grain stubble remained; thus geese resorted to feeding primarily on tidal flats. By late December geese no longer used the study area.

Discussion

It is not possible at present to determine what proportion of the North Atlantic Flyway population of Canada geese migrate through Prince Edward Island. Midwinter censusing of geese along the Atlantic coast has indicated a sharp increase over the past 3 decades (Bellrose, 1976). Aerial surveys conducted along the Prince Edward Island coastline in late autumn by the Canadian Wildlife Service and the P.E.I. Fish and Wildlife Division also indicate a dramatic increase recently in the number of geese. November surveys from 1967-1975 resulted in counts of from 8,000-10,000 geese. From 1976-1979 the number of geese observed during late fall surveys averaged almost 20,000 birds.

These numbers do not represent total counts since some geese would be feeding inland during the coastal flights. The rapid increase in numbers of geese visiting Prince Edward Island in both spring and fall may be due to changes in agricultural practices. Hankla and Rudolph (1967) report that the increased use of mechanized equipment and combining of small fields into large open blocks coincided with a change in feeding areas for Canada geese from coastal areas to inland agricultural

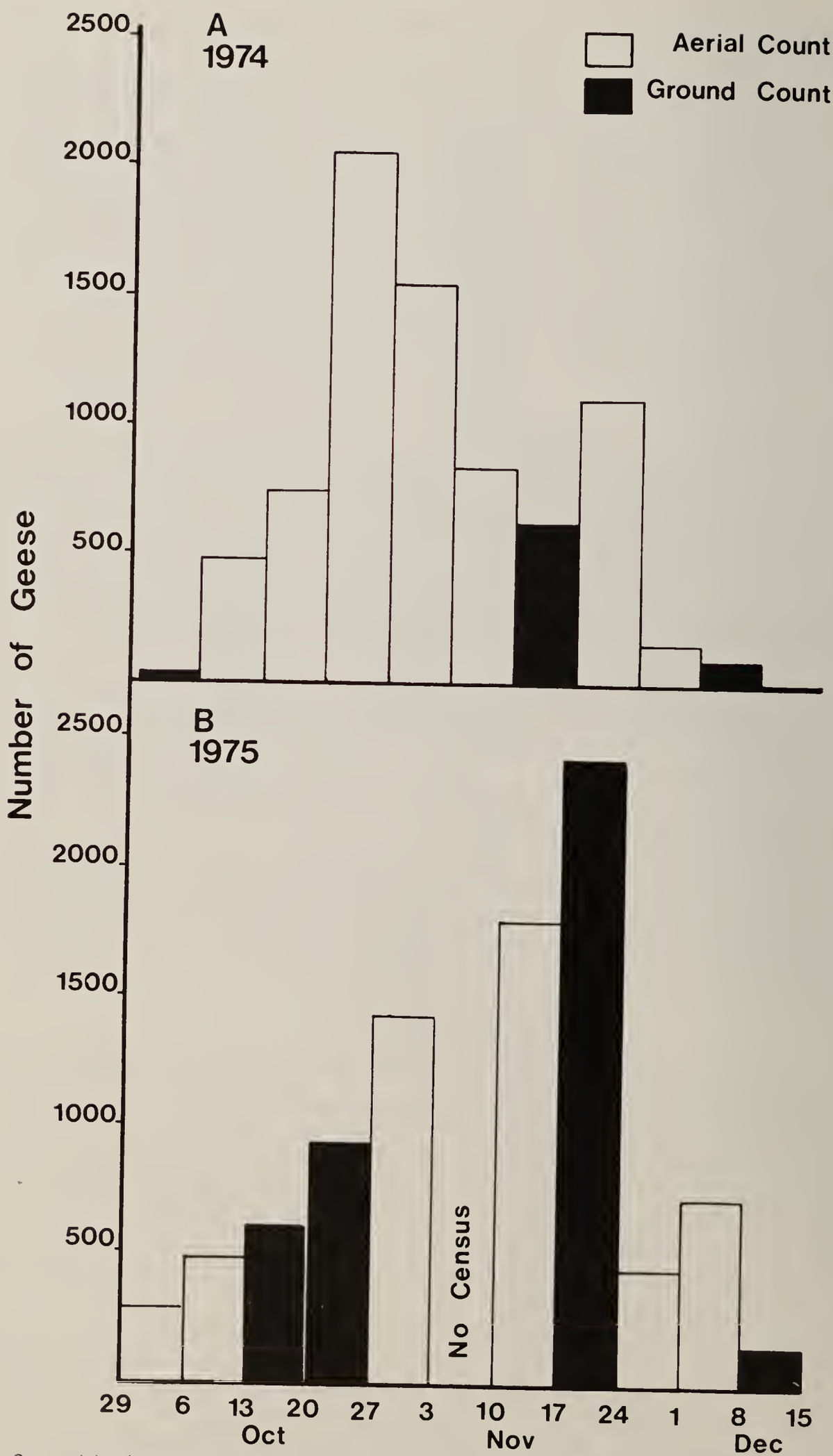

Fig 3 Maximum numbers of Canada geese observed weekly in autumn on southwestern Prince Edward Island, 1974-1975.

fields in north Florida and south Georgia. The average farm size on Prince Edward Island has increased from 32 to 68 ha over the last 85 years (Royal Commission Report 1973). Corporate farming operations and government incentives to remove hedgerows have led to much larger fields and because of their wind-swept nature, sections of these have little snow cover, thus providing exposed feeding sites long before snow and ice thaw on rivers and marshes.

Although quantitative data are limited, the period of spring hyperphagia for Canada geese appears variable; it may be completed before they leave the wintering grounds (McLandress and Raveling 1981a) or during migration (Hanson 1962). When feeding on agricultural land, geese in spring spent 6-12 hours daily on Prince Edward Island farmland. Reed et al. (1977) found that Canada geese migrating through the St. Lawrence Valley, Quebec, spent 4-8 hours per day on farmland. The proportion of spring weight gain that occurs on these migratory stopover areas is unknown, and it may change annually or vary according to length of migratory flight.

The literature on how geese exploit agricultural lands is substantial and relative forage values have been compared (Newton and Campbell 1973, Kear 1963), but the question of the nutritional corresponding reproductive consequences of switching from coastal feeding areas to agricultural lands has barely been addressed. Generally, cultivated crops are considered to be more nutritious than marsh plants (Kear 1963), but it is unknown whether agricultural lands can provide the balance of nutrients necessary for breeding. However, Reed (1976) noted that many geese which have made the switch to agricultural lands have increased their numbers. Current agricultural practices on Prince Edward Island are providing increased acreages for feeding, and thus the province can be expected to play an increasingly important role in ensuring that migrating geese in the Atlantic Flyway arrive on the breeding grounds in peak reproductive condition.

To proceed beyond this study, detailed observations on time spent foraging, type and amount of food items ingested and subsequent weight gain would be extremely valuable in determining the importance of migratory stopover areas. With color-marked individuals or flocks, precise information about length of stopover period, flock movements and behaviour could be obtained. Finally, we know almost nothing of relationships between habitats used for foraging, length of migration stopover, and the age and reproductive status of Canada geese.

Acknowledgements

This research was part of an interdisciplinary study of the Dunk River conducted by the University of Prince Edward Island and government agencies. Funding was provided by the Senate Research Committee of the University and the National Research Council of Canada. We acknowledge field assistance from B. Butler, R. Curley, E. Hickey, D. Martin, M. Rouse, D. Smith, and J. Steeves. The Prince Edward Island Fish and Wildlife Division provided equipment, advice and airplane funding, and E. Morello prepared the figures. We are grateful to D. Ankney, R. Curley, R. Dibblee, A.J. Erskine, A.R. Lock, and D. McAskill for criticisms of various drafts of the manuscript.

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ZYMOTYPES IN *VACCINIUM* SECTION *CYANOCOCCUS* AND RELATED GROUPS.

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The potential use of the isoenzyme technique for resolving species deliniations within Vaccinium section Cyanococcus was investigated. Only young leaf tissue produced reproducible results upon staining for malate dehydrogenase and phosphoglucose isomerase. These zymograms showed great uniformity among species of V. section Cyanococcus and species of other sections of the genus. While peroxidase and esterase enzyme banding patterns were not as clear nor reproducible, their zymoytypes varied little among species tested. It is hypothesised that the overall similarity among species of V. section Cyanococcus in isoenzyme patterns reflects the youth of this group.

La possibilité d'utiliser la technique des isoenzymes pour décrire les espèces du genre *Vaccinium* section *Cyanococcus* fut étudieé. Des resultats reproductibles m'ont été obtenus pour les colorations de la malate dehydrogénase et la phosphoglucose isomerase qu'en utilisant des tissues provenant de jeunes feuilles. Les patrons de ces enzymes ont montré l'existance d'une grande uniformité parmi les espèces du genre *Vaccinium* section *Cyanococcus* et parmi les espèces des autres sections de ce genre. Mèmi si les patrons enzymatiques obtenus pour la peroxidase et l'α-esterase ne furent pas aussi précis et reproductibles, ces enzymes ont montré peu de variation parmi les espèces étudieés. Une hypothese est emise selon laquelle, la ressemblance générale, des patrons enzymatiques des espèces de *Vaccinium* section *Cyanococcus* reflèterait l'apparition récente de ce groupe.

Introduction

* The provenance of all individuals of the species tested is listed in Appendix 1.

Vaccinium section Cyanococcus A. Gray consists of nine species, eight of which are restricted to eastern North America, and one, *V. myrtilloides*, is boreal and transcontinental (Vander Kloet, 1982). Species referred to this section have verrucose twigs of the current season; dimorphic perennating buds (viz. floral and vegetative) covered with several (>5) scales; corymbose inflorescences; pedicels articulated with the calyx; awnless stamens included in urceolate or cylindrical corollas; and pseudo-10 loculed berries.

Camp (1942, 1944, and 1945) recognized 24 phylogenetic units, labelled for convenience as species, in *V. section Cyanococcus*. Subsequent observations made by Vander Kloet (1972, 1977, 1980, 1982) showed, however, a high incidence of transitions within species of the character states used by Camp for his classification. Vander Kloet (1972, 1977, 1980, 1982) turned to Adansonian principles and numerical taxonomy (Sneath and Sokal 1973) to re-organize the section. The phenetic species defined by these techniques had unique habitat requirements and together with ethological factors gave confidence in their existence as genetic entities (Vander Kloet 1983).

To date biochemical evidence has not been applied to test this systematic rearrangement within *V. section Cyanococcus*. Indeed, taxonomically significant biochemical data involving the genus have been scant and thus far restricted to the use of seed material (Frohne and John 1978). Seeds of *Vaccinium* species are small and their high lipid content makes protein extraction troublesome (Vander Kloet, unpublished data). On the other hand, leaves were continuously available from greenhouse plants. This study uses leaf material in order to discover electrophor-

etic differentiation of enzymes not only among species of *Vaccinium section Cyanococcus* but also among several sections.

Materials and Methods

Leaves for electrophoretic study were chosen from individuals of species in *V. section Cyanococcus (viz. V. boreale, V. corymbosum, V. darrowii, V. myrtilloides* and *V. tenellum)*, as well as from members of species in other sections (*viz. V. section Myrtillus: V. membranaceum, V. myrtillus* and *V. parvifolium; V. section Oxycoccus: V. macrocarpon; V. section Vaccinium: V. uliginosum)*, which were introduced to make intrageneric comparisons. All plants used were grown from seed at Acadia University greenhouse under uniform conditions.

Ten newly unfurled leaves and ten hardened mature leaves were taken from each plant. These were ground separately with sterilised sea sand and chilled extraction buffer (in the ratio 1 gm tissue (fr. wt.) to 4 ml buffer) in a chilled mortar and pestle. The extraction buffer found to minimize phenolic interference was 0.5 M phosphate buffer at pH 7.0, including the following reagents at indicated concentrations: cysteine HC1, 15 mM; DIECA (diethyldithiocarbamic acid) 11 mM; dithiothreitol, 20 mM; EDTA (ethylenediaminetetraacetic acid), 20 mM; Polyethylene glycol, 6% (wt./vol.) and insoluble PVPP (polyvinylpolpyrrolidone) at 4% (wt./vol.). This solution was made 24 h before grinding, to hydrate the polymer, PVPP (Loomis and Battaile, 1966).

Once a liquid slurry was reached, leaf extracts were squeezed through four layers of cheesecloth into chilled beakers. Wicks of Whatman No. 1 filter paper were used to absorb this exudate, and these were inserted in 10.5% starch gels. Gels were run at 20 mAmp for 4-5 h.

Two concentrations: A(0.3 m) and B(0.115 M), of tris-citrate electrode buffer were tested at pH 7.5. The corresponding gel buffer in each case was a fivefold dilution of the electrode buffer (adapted from buffer system 1 of Shaw and Prasad, 1970).

Malate dehydrogenase (MDH) and phosphoglucose isomerase (pg 1) were stained according to Schaal and Andersen (1974). The recipe of Shaw and Prasad (1970) was followed for staining α-esterase, and a modification of their recipe for peroxidase staining was made employing o-dianisidine for enzyme staining.

The distance of enzyme band migration from the point of insertion was recorded. Relative migration (RM) was calculated based on the furthest anodal band (RM + 1.0) from the insertion RM 0). Cathodal electromorphs were similarly computed with a negative RM.

Preliminary trials with the following enzyme systems using the recipes of Schaal and Anderson (1974) were unsuccessful: acid phosphatase, alcohol dehydrogenase, alkaline phosphatase, catalase, glucose-6-phosphate dehydrogenase, glutamate dehydrogenase, glutamate oxaloacetate dehydrogenase, leucine-aminopeptidase, 6-phosphogluconate dehydrogenase, and xanthine dehydrogenase.

Results

The extraction technique described herein was found best for preventing browning of extracts and producing reproducible enzyme banding. Interference from phenolics, however, still limited the investigation to four enzyme systems (*viz.* α-esterase, malate dehydrogenase, peroxidase and phosphoglucose isomerase) and of these, only peroxidase showed activity when mature leaf extracts were tested.

When young flush leaves were used, the effects of phenolic oxidation could still be witnessed unless extractions were kept chilled. In fact one experiment was conducted using young leaf material of *V. corymbosum* (Yar No. 31, 42; HB No. 42 Appendix), in which one set of extracts was allowed to come to 20°C while a duplicate set was kept chilled. The first set at room temperature were visibly browned while the chilled extracts remained green. Browned extracts showed no PGI activity and the typical slow MDH electromorph under buffer system A (see Fig 1) was deleted. α-Esterase zymotypes for browned extracts showed more streaking than did their chilled counterparts, and enhanced migration of peroxidase electromorphs resulted when browned extracts were run.

These effects could be duplicated by the addition of leaves of the evergreen *V. corymbosum* (Fusc. 31, 49) to grinding mixtures of young *V. corymbosum* (Yar 31, 42) leaves.

Conflicting α-esterase and peroxidase zymotypes were obtained for several individuals* of the *V. section Cyanococcus* species in separate electrophoretic trials. α-Esterase and peroxidase zymotypes failed to reveal reproducible intrasectional differences. A three banded peroxidase zymotype (Rm −0.3, +0.25, +1.0) was shared by the majority of individuals (*viz. V. boreale:* 327975, 39976; *V. corymbosum:* Fusc. 11, 15, 31, 49; HB 39; Yar 31, 42, 48, 57, 69, 76; *V. darrowii*; Abs 10; *V. tenellum:* 1428574; 128574; 121675) of *V. section Cyanococcus* species. A four banded α-esterase zymotype (Rm −0.3, −0.2, +0.6, +1.0) was produced by individuals of *V. corymbosum* (Yar 48, 57, 69 and 76) and *V. boreale* (327975, 39976). Other individuals tested demonstrated α-esterase patterns which were assorted combinations of various electromorphs of the four banded zymotype.

The inconsistent nature of the α-esterase and peroxidase results caused us to concentrate instead on the more accountable PG1 and MDH enzyme systems. These were found to be quite susceptible to phenolic interference and even the young leaves of several species *(viz. V. darrowii, V. tenellum,* and the evergreen members of *V. corymbosum)* were unsuitable for PGI and MDH electrophoretic study.

All individuals of species of *V. section Cyanococcus* (*viz. V. boreale:* 327975, 39976; *V. corymbosum:* HB 39, 22; Yar 31, 39, 42, 48, 57, 68, 69, 76, 80; *V. darrowii* LII313; *V. myrtilloides* 21881, 517773) and of other sections of the genus *viz. V. section Myrtillus; V. myrtillus; V. membranaceum:* 42979, 629879; *V. parvifolium:* 229879, 731879; *V. section Oxycoccus; V. macrocarpon:* 6121081, 1271081; *V. section Vaccinium, V. uliginosum:* 613821) produced a uniform two banded zymotype (Rm. +0.7, +1.0). One individual of *V. darrowii* tested (*viz.* ABs 6) produced a single slow (Rm +0.7) electromorph. Follow up work was not possible due to the age of the tissues.

All species of the sections tested (*viz. V. section Cyanococcus; V. boreale* 327975, 39976; *V. corymbosum:* Yar 31, 39, 42, 48, 57, 68, 69, 76, 80 HB 22, HB 39; *V. darrowii, Abs LII313; V. myrtilloides* 21881, 517773; *V. Tenellum* 1428574, 128; *V. Myrtillus: V. membranaceum* 629879; *V. myrtillus* 11277; *V. parvifolium:* 731879: *V. Oxycoccus: V. macrocarpon* 1271081: *V. Vaccinium: V. uliginosum* 613281) except *V. darrowii* (*viz,* Abs 6, 10) exhibited a monomorphic double banded MDH zymotype, when buffer system "A" was used (e.g. Fig 1). *V. darrowii* individuals, Abs 6 and 10, expressed the single slow MDH band only.

*α-esterase - *V. corymbosum:* Fusc. 9, 11; HB 22; Yar 31, 42; WS 2; *V. darrowii* Abs LII 313; *V. tenellum* 1428574

peroxidase—*V. corymbosum:* Fusc. 9, 15; Yar 48, 57; *V. darrowii:* Abs 6, 10; *V. tenellum* 1428574

Under the more dilute buffer regime "B" it was discovered that the slow MDH electromorph of *V. corymbosum* Yar 31, 42, 48 and 68, see Fig 1) and of V. myrtillus (31076) was composed of two electromorphs of very similar mobility (Rm* .8 and .6, 1.0 and .6 respectively (see Fig 2).

Discussion

Phenolic interference was observed for all enzyme systems investigated. The extraction technique was inadequate for older leaf tissue. Only the peroxidase system was stainable using mature leaf extracts. α-Esterase, MDH, and PGI zymotypes were all susceptible to modification by phenolics. This was suggested by the simple addition of mature leaves to young leaf extracts.

Browning of extract was closely correlated with enzyme banding quality. The slow MDH electromorph was more susceptible to interference than the fast electromorph, and could be deleted while the more resistant fast MDH electromorph was preserved. This situation might easily be misinterpreted without adequate replication with young tissues. A similar case was reported by Townsend (1970) and Dirr et al (1972), who reported no nitrate reductase activity in blueberry leaf homogenates. Enzyme activity could only be detected when *in vivo* techniques were used (Dirr et al 1972).

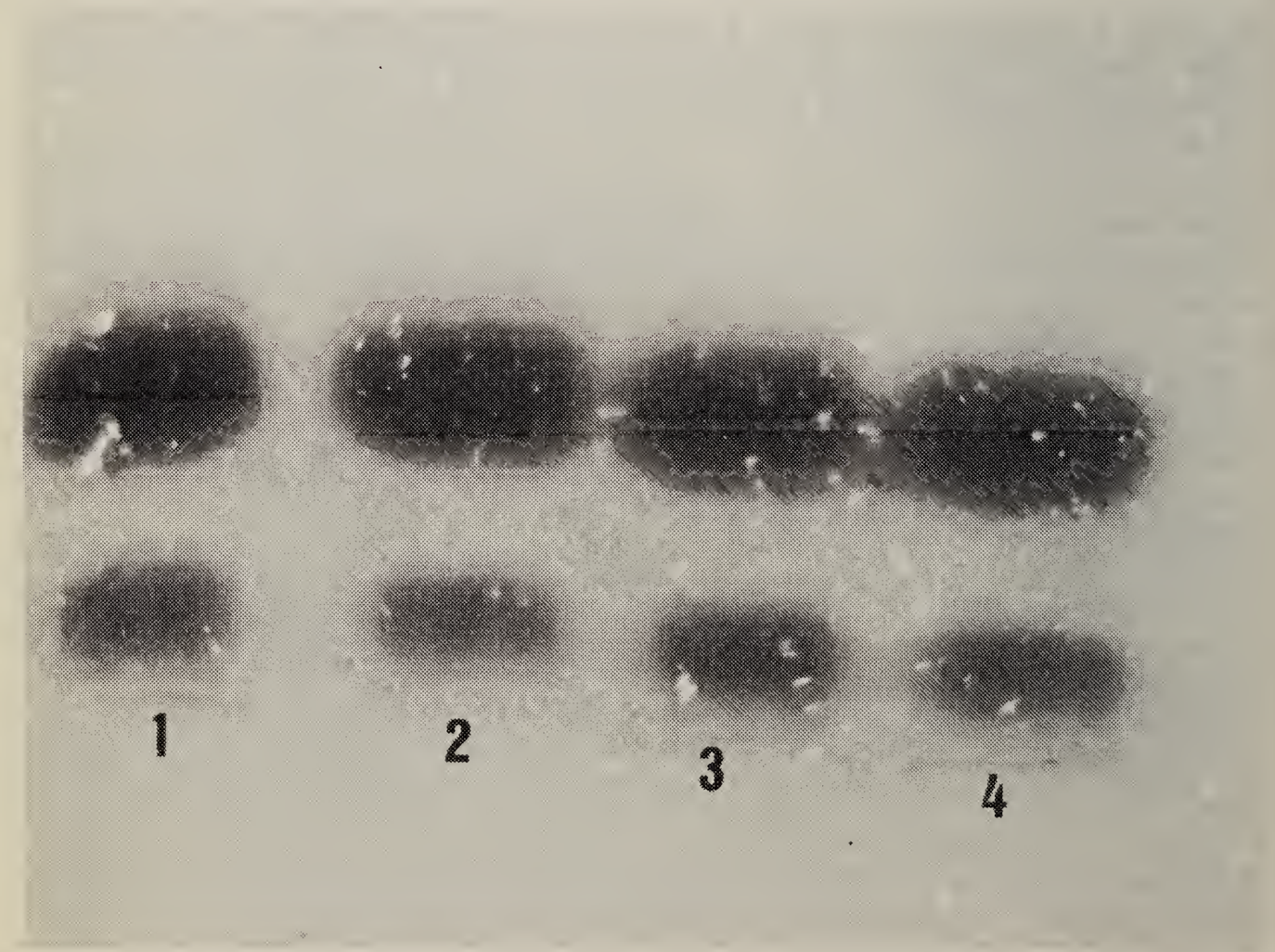

Fig 1 MDH zymotype of *V. corymbosum* using concentrated buffer system "A". (1 = YAR 48; 2 = YAR 57; 3 = YAR 69; 4 = YAR 76).

*Rm based on the fastest of the *V. myrtillus slow anodal electromorphs.*

Soltis et al (1980) simplified the technique of Kelley and Adams (1977) and omitted centrifugation, separatory procedures and the costly germanium dioxide. Similarly we found no benefit from centrifugation or germanium dioxide in this study. However the potential for separatory procedures should be investigated with blueberry leaves, because of the limitations associated with the present extraction process.

These limitations were further manifested in the variable results obtained upon peroxidase and α-esterase staining. In spite of these inconsistencies however, the majority of *V. section Cyanococcus* species tested (*viz. V. boreale, V. corymbosum, V. darrowii* and *V. tenellum)* exhibited a three banded peroxidase zymotype. Moreover all these species possessed various α-esterase electromorph combinations of the four banded zymotype found for several *V. corymbosum* and *V. boreale* individuals.

The conservative nature of *V. section Cyanococcus* zymotypes was also found for PGI and MDH enzyme systems. These were monomorphic throughout the *V. boreale, V. corymbosum* and *V. myrtillus* individuals tested. This conservatism extended to other sections of the genus (*viz. V. section Myrtillus, V. section Oxycoccus,* and *V. section Vaccinium*) which shared the same PGI and MDH zymotypes found for *V. section Cyanococcus* species.

When the more dilute buffer system "B" was used, however, *V. corymbosum* (of V. section Cyanococcus) and *V. myrtillus (of V. section Myrtillus*) were each found to possess an additional slowly migrating MDH electromorph. This could be used to differentiate them from other species as well as from each other. PGI results were unchanged using the different buffer concentrations.

Fig 2 MDH zymotype of *V. myrtillus* using dilute buffer system "B". (1 = 31076; 2 = 31076 x 11277; 3 = 11277).

The overall zymotype similarity observed throughout *V. section Cyanococcus* for all enzyme systems investigated (*viz.* α-esterase, MDH, peroxidase and PGI) supports the youth of the group. The ancestral *Cyanococcus* is believed to have entered the North American continent via the Proto-Antilles from South America, and to have invaded the sand dunes of peninsular Florida during the Tertiary (Vander Kloet 1982). However despite adaptive radiation, which included the loss of evergreen and xeromorphic characters, homoploids developed no incompatibility systems. In fact there is circumstantial and experimental evidence that *V. corymbosum* resulted from the introgression of *V. tenellum* into the range of *V. darrowii* during the Pleistocene (Vander Kloet 1980).

Various authors (e.g. Soltis, 1982; and Schwaegerle and Schaal, 1979) have discovered low amounts of enzyme polymorphism in groups where extensive colonization has occurred in the post-Wisconsin vacuum. This has been attributed to the processes of founder effect and genetic drift. We venture that a similar situation may have occurred during the divergence of the *Vaccinium section Cyanococcus* group. Moreover speciation in such a group has probably been effected by gene regulatory site changes, as Carson (1976) has argued.

Electrophoretic evidence can only be marshalled to support these hypotheses if appropriate developments are made in the extraction techniques of leaf enzymes. This has been done successfully with many conifers recently (Kelly and Adams 1977, Mitton et al. 1979), work must be done similarly on extraction in ericaceous taxa.

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Appendix

Provenance of specimens used in the analysis; Vouchers at ACAD.

Vaccinium section Cyanococcus A. Gray

1. *V. corymbosum* L. diploid plants: Fusc 9, 11, 15, 31, 49 and WS2—Archbold Biological Station, 13 km S of Lake Placid, Highlands County, Florida; tetraploid plants: HB 22, 39 and 642—Hebert Bog, Upper Rock Lake, Frontenac County, Ontario; Yar 31, 42, 48, 56, 68, 69, 76 and 80—Lake George and Leap Frog Lake, Yarmouth County, Nova Scotia.
2. *V. darrowii* Camp, ABS6, ABS10, L11313—Archbold Biological Station, 13 km S of Lake Placid, Highlands County, Florida.
3. *V. tenellum* Aiton, 128574—Rowland, Robeson County, North Carolina; 1428574—Myrtle Beach, Horry County, South Carolina; 121675—8 km N of Emporia, on the Greenville-Sussex County Line, Virginia.
4. *V. myrtilloides* Michx. 517773 and 21881—Dominion Atlantic Railway Right-of-Way, Wolfville, Kings County, Nova Scotia.
5. *V. boreale* Hall & Aalders, 327975—Kennington Cove, Cape Breton County, Nova Scotia; 39976—Cape Spear, Avalon Peninsula, Newfoundland.

Vaccinium section Myrtillus Dumortier

6. *V. myrtillus* L. 31076 and 11277—Reycroft Moor, near Bingley, West Yorkshire, England.
7. *V. membranaceum* Douglas, 629879—Mt. Seymour Provincial Park, North Vancouver, British Columbia: 42979—Paradise Meadows, Forbidden Plateau, Vancouver Island, British Columbia.
8. *V. parvifolium* Smith, 229879—Mt. Seymour Provincial Park. North Vancouver, British Columbia; 731879—River Jordan, Vancouver Island, British Columbia.

Vaccinium section Oxycoccus (Hill) K. Koch.

9. *V. macrocarpon* Aiton 6121081—Kennington Cove, Cape Breton County, Nova Scotia; 1271081—Hebert Bog, Upper Rock Lake, Frontenac County, Ontario.

Vaccinium section Vaccinium

10. *V. uliginosum* L. 613281—Cape St. Francis, Avalon Peninsula, Newfoundland.

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INDUCTION AND SUBCULTURE OF CALLUS FROM PETIOLES OF *FRAXINUS AMERICANA* (L.), WHITE ASH.

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Terminal buds of *Fraxinus americana* L., white ash, were forced in a 16 hr photoperiod at 28°C. Proximal petiole segments were excised, disinfested, and plated on semi-solid Murashige/Skoog medium, containing 2,4-D and kinetin used singly or in various combinations.

After 3 weeks incubation, the best callus production occurred when 1.0 ppm 2,4-D + 1.0 ppm kinetin were applied to either light- or dark-grown segments. On the same medium, subcultured callus grew better in the light. Some calluses could be subcultured at regular intervals in the dark for as long as 24 months, on Linsmaier/Skoog medium with pyridoxine, 2,4-D and kinetin.

La croissance des bourgeons terminau de *Fraxinus americana* L., le frêne blanc, fut hâtée par une photoperiode de 16 hr. à 28°C. Les segments proximaux des pétioles furent coupés, désinfectés et furent piqués sur un milieu semi-solide de type Murashige/Skoog, content du 2,4-D et de la kinetine séparément on en combinaisons variées. Après trois semaines d'incubations, la meilleure production de cals fut enrégistrée quand les segments croissant en lumière ou à l'obscurité furent traités avec un solution de 1.0 ppm de 2,4-D + 1.0 ppm de kinetine. Pour le même milieu, les sous-cultures de cals croissaient mieux en lumière. Quelque cals ont pa être mis en sous-culture, à intervalle régulier à l'obscurité, pour une période aussi longue que 24 mois en utilisant un milieu de type Linsmaier/Skoog continent de la pyridoxine, de 2,4-D, et de la kinetine.

Introduction

Mott (1981) has reviewed the establishment and uses of callus cultures from trees. He notes the lengthy history of these studies and the fact that over 200 species have been investigated. From this and other reviews (Bonga 1980, 1981; Sommer & Caldas 1981; Karnosky 1981) it seems clear that major breakthroughs in propagative techniques *in vitro* have yet to be realized, especially regarding forest trees. Nonetheless, tree callus has proven to be useful in studies of somatic embryogenesis (Sondahl *et al.* 1981), organogenesis (Venverloo 1973; Srivastava & Steinhauer 1981) and differentiation (Wright & Northcote 1973). In recent decades relatively few studies on the genus *Fraxinus in vitro* have appeared. Wolter and Skoog (1966) started callus on root-sprout segments of *F. pennsylvanica*. Continuous subculture was possible on a modified Reinert and White's medium, with myoinositol, pyridoxine and an auxin. Doley and Leyton (1970) examined growth and differentiation of stem callus from *F. excelsior* L. Both the water potential of the medium and indoleacetic acid were influential.

Recently, we began work on various types of somatic cells of *F. americana* L., white ash, with the long-range goal of vegetative propagation. In this preliminary report we document conditions for callus induction and subculture from petiole sections.

Methods

Most of the experiments used plant material from mature trees on the eastern edge of MacDonald Lake, Dartmouth, Nova Scotia, unless otherwise described. Branches were harvested in January, 1982 and twigs from these were stored in darkness at 4°C. Prior to each experiment, terminal buds were forced under controlled conditions in an attempt to generate "uniform" leaf material for inoculation. Twigs were brought to room temperature, trimmed to a length of

about 25 cm and placed standing in containers of tap water. Batches of such twigs were incubated at 28°C under a 16 h photoperiod. Illumination was provided by 4 fluorescent lamps (General Electric F40 CW) and 3 incandescent ones (General Electric 40 W), set at 40 cm above the containers (55 μ Einsteins sec^{-1} M^{-2}). Terminal buds flushed in about 2 wks usually producing 2 pairs of expanded leaves. Petiole segments proximal to the leaflets were excised and disinfested as follows:

(a) 1 min in 70% ethanol
(b) 3 five-min rinses in sterile distilled water
(c) 10 min in aqueous commercial bleach (Javex: water 1:1)
(d) 3 five-min rinses in sterile distilled water

Petiole segments were transferred to a sterile Petri dish, the ends were trimmed off and then 0.5 cm segments were cut for inoculation. The basal culture medium (BM) was that of Murashige and Skoog (Flow Laboratories, Virginia, U.S.A.), with 3% sucrose, 0.8% agar, at pH 5.6. Double distilled water was used throughout. BM was sterilized by autoclaving 15 min. The auxin, 2,4-dichlorophenoxyacetic acid (2,4-D) and the cytokinin, kinetin (KIN), were tested for their ability to induce callus formation. Each hormone was tested alone at 0.01, 0.1 and 1.0 ppm, and in all combinations using those 3 concentrations. Stock solutions of hormones were sterilized by passage through a Millipore filter apparatus with 0.22 μ pore size. Requisite volumes of hormone stocks were added to cooling autoclaved solutions of BM. Media were decanted into presterilized plastic Petri dishes (8.5 cm diameter) at 25 ml per dish, and allowed to set. Control plates consisted of BM only. Two petiole segments were inoculated into each dish; dishes were sealed with masking tape. Cultures were incubated for 3 wks in the light under the same conditions as the flushing twigs, or in a dark cabinet in the same room. The dark experiment was attempted three times and the light experiment twice. For most of the 16 treatments, a total of 12-15 petiole segments have been cultured. At termination, a semi-quantitative assessment of callus production was made as follows. The two ends of petioles were examined carefully using a Wild M5 dissecting microscope. Using the 12 X objective and a calibrated ocular micrometer aligned along the long axis of the segment, callus size was measured, from the cut end of the petiole to the outer edge of the callus mass (Fig 1). This procedure afforded a sensitive detection method for even small amounts of petiolar callus. When it became obvious that BM with 1.0 ppm 2,4-D and 1.0 ppm kinetin was the most effective medium, its effects were examined in repeat experiments. In the dark, an additional 34 petiole segments were cultured, and an additional 64 in the light.

To produce callus for subsequent subculture and growth measurements, we first inoculated petioles on BM + 1.0 ppm 2,4-D and 1.0 ppm KIN. After 3 weeks, callus from dark-grown cultures was excised and taken through 2 dark subcultures, each of 3 weeks duration. The medium was of the same composition as before, with 40 ml aliquots dispensed in baby food jars with Parafilm (American Can Co.) closures. This tissue was then cut into cubes measuring 3 mm to the side and inoculated on the usual medium. These cultures were incubated in the dark, or under the same light conditions as previously described. After 3 weeks, the fresh weight of each piece was determined on an analytical balance. This growth experiment was repeated once.

A different collection of plant material was used for long-term experiments. Twigs collected in late June, 1979, in a ravine near Wentworth, Nova Scotia, were stored for 2 weeks in the cold, then flushed as previously described. Disinfested petiole segments were inoculated on Linsmaier/Skoog medium containing kinetin at 0.1 ppm and 2,4-D at 1.0 ppm, in 50 ml Erlenmeyer flasks in the dark. Calluses were subcultured on the same medium in 125 ml Erlenmeyer flasks, with a passage

time of 2-3 weeks for the first four passages, and 4-5 weeks for the remaining passages for a total of 24 months. After the sixth passage, pyridoxine (0.1 mgm L^{-1}) was included in all media.

Results

It soon became evident that the medium BM + 1.0 ppm 2,4-D + 1.0 ppm KIN generated the largest callus masses (Table I). The largest (average) callus was observed on dark-grown petioles on this medium. Individual pieces as large as 4.40 mm were measured. In separate experiments, this result was substantiated. Thus, 34 additional dark-grown segments averaged 2.25 mm callus, whereas 64 segments in the light averaged 1.91 mm callus.

Periodic observations of the segments on this 'optimal' medium revealed that after one week, the cut ends had swollen and callus had just appeared. After two weeks, a compact nodular callus had developed, often wider than the swollen ends (Fig 1). Dark-grown callus was either gray-white or a light tan colour, while in the light, callus was white on its surface, with a light-green cast to the underlying callus tissues. Often there was a substantial difference in the amount of callus produced at the two ends of an individual segment. Some dark-grown segments produced substantial amounts of callus on the petiole surface in contact with the semi-solid medium.

Table I Callus production from ash petioles on various media

Hormone supplement (ppm)		Average callus size (mm) Dark-grown	Light-grown
None	(BM)	0.04	0.14
2,4-D	(0.01)	0.10	0.17
	(0.1)	0.26	0.18
	(1.0)	0.57	0.50
KIN	(0.01)	0.07	0.06
	(0.1)	0.14	0.14
	(1.0)	0.16	0.09
2,4-D	(0.01)		
+ KIN	(0.01)	0.14	0.13
	(0.1)	0.11	0.18
	(1.0)	0.16	0.19
2,4-D	(0.1)		
+ KIN	(0.01)	0.24	0.22
	(0.1)	0.16	0.18
	(1.0)	0.42	0.37
2,4-D	(1.0)		
+ KIN	(0.01)	0.38	0.30
	(0.1)	0.46	0.44
	(1.0)	1.80	1.21

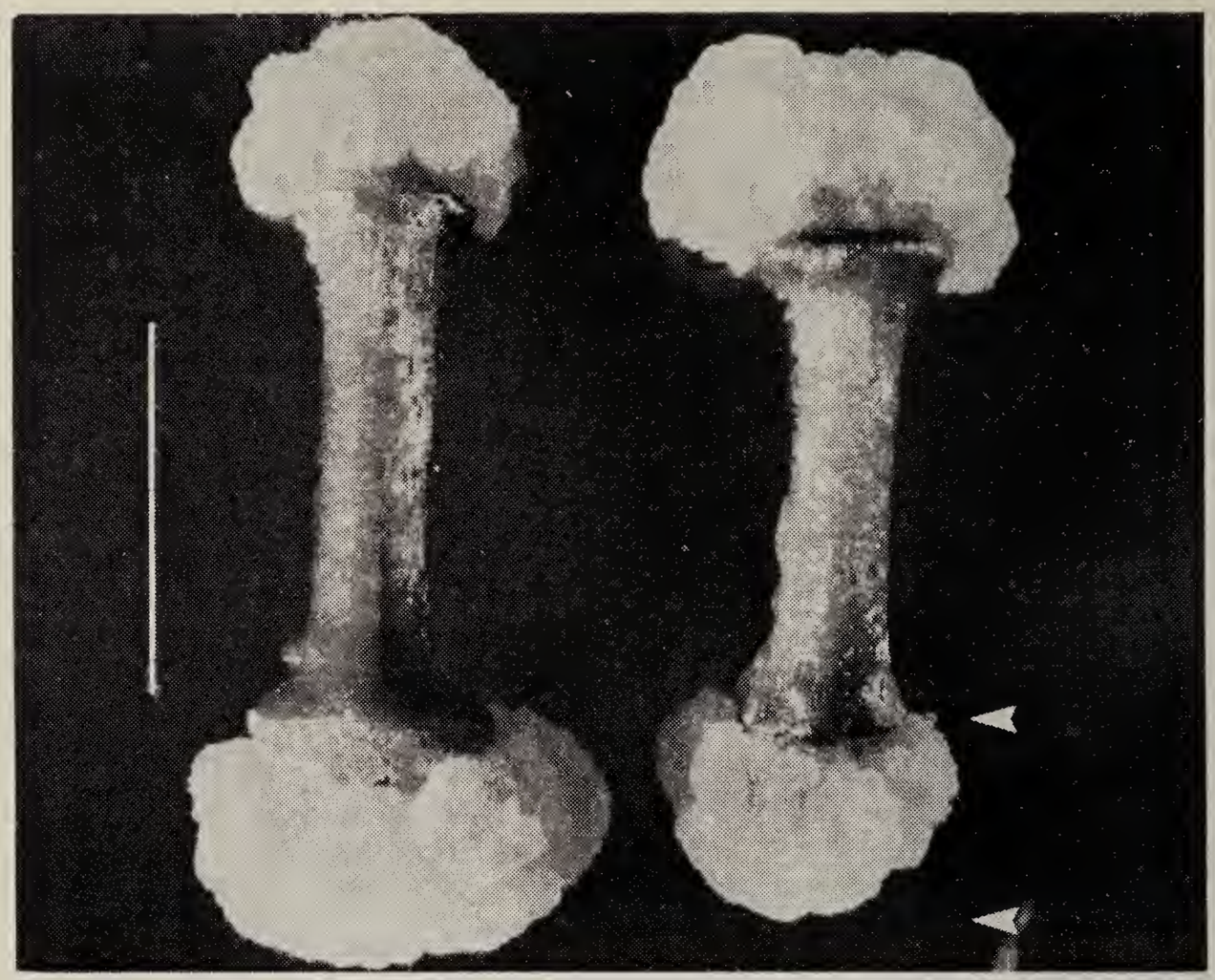

Fig 1 Petiole segments cultured for 21 days in the light. Arrows indicate the measurement taken as an index of callus size. Bar is equal to 0.5 mm.

The majority of the other hormone supplements produced only modest amounts (less than .50 mm) of callus (Table I), except for 2,4-D at 1.0 ppm. Within any one of the low-yielding treatments a variable number of cut ends had no measurable callus. In some treatments, the proportion of such segments was over 50% of the sample. Contrastingly, BM + 1.0 ppm 2,4-D + 1.0 ppm KIN invariably yielded some callus on all cut ends.

The average starting weight of callus cubes used in the growth determinations was 30 mg (Table II). Over the two experiments, the light-grown pieces showed a higher average growth index (6.5) than did their dark-grown counterparts (5.4, Table II). Obviously there was considerable variation in growth, as indicated by the final weight ranges.

Calli from the Wentworth material had a requirement for pyridoxine. Unless the latter was included in media after the 6th passage, calli turned brown and stopped proliferating. With pyridoxine, calli continued as white proliferating masses in the dark. After 23 passages, a growth index of 2.2 was measured for these cultures.

Discussion

In our view, we have established a reliable method for consistently inducing ash callus which can then be subcultured. For good callus proliferation on the primary inocula, both 2,4-D and kinetin were essential. Somewhat similar results have been found with leaf explants from other woody species. For example, leaf *blade* explants responded by callusing well on media supplemented with naphthalene acetic acid (NAA) and kinetin, in the case of *Citrus grandis* (Chaturvedi and Mitra 1974), *Malus pumila* Mill cv. Golden Delicious (Mehra and Sachdeva 1979) and

Table II Fresh weight increases of subcultured ash callus[a]

Experiment	Average callus weight (mg) Initial	Final	Final Weight Range (lowest-highest)	Growth Index[b]	Average Growth Index
Light-grown					
1.	29.6	213.1	(131.2-	7.2	
	(30)[c]	(20)[d]	294.4)		6.5
2.	27.5	156.6	(82.0-	5.7	
	(30)	(24)	318.4)		
Dark-grown					
1.	29.6	165.3	(70.6-	5.6	
	(30)[c]	(14)[d]	373.0)		5.4
2.	27.5	140.6	(70.4-	5.1	
	(30)	(20)	225.0)		

[a]Growth period = 3 weeks; [b]Average final weight/average initial weight; [c]For each experiment, 30 representative cubes were weighed and discarded; [d]Number of replicate pieces of callus.

Pyrus communis var. communis (Mehra and Jaidka 1979). In contrast, leaf blade tissue of *Prunus amygdalus* seedlings required only an auxin for callus formation (Mehra and Mehra 1974). In an extensive study using 7 mm^2 leaf squares of *Coffea arabica* cv. "Bourbon", kinetin and 2,4-D in a 2:1 ratio were found to be superior to a wide range of other auxin/cytokinin combinations (Sondahl *et al.* 1981). Leaf *petiole* explants of *Coffea arabica* cv. "Mundo novo" callused on L/S medium with 2,4-D and kinetin (Sharp *et al.* 1973), as in the present study. Petioles of *Tilia americana* L. callused on White's medium with 2,4-D and 20% coconut milk (Barker 1969). An auxin and a cytokinin have been used for callus induction in other tissues from woody species. For example, stem segments of 11 species of Rosaceae callused in response to both hormones (Coffin *et al.* 1976) as in several cultivars of *Malus pumila* (Chong and Taper 1974). On the other hand, root sprouts of *Populus tremuloides* callused on Wolter's medium with 2,4-D only (Winton 1968a, 1968b), and hypocotyl segments of *Acer pseudoplatanus* needed only NAA for callus induction (Wright and Northcote 1973). Stump sprouts of *Fraxinus pennsylvanica* callused on Reinert and White medium with kinetin at 1 mg L^{-1} (Wolter and Skoog 1966). It thus appears that the hormonal requirements for callus induction in woody species are quite different between species. Precise comparisons are obviously difficult, due to differences in basal media, plant age and culture conditions.

We have also demonstrated that ash petiole callus can be readily subcultured in the light or dark, and for prolonged periods. Growth indices of subcultured callus of our *F. americana* may be compared with indices in other studies. Growth indices similar to white ash have been reported for *Prunus persica, Prunus nigra* (Coffin *et al.* 1976) and for *Malus pumila* cv. Cortland (Chong and Taper 1972). Considerably higher growth indices were documented for callus of *Prunus cerasus, Prunus avium, Pyrus communis, Amelanchier arborea, Crataegus* x *mordensis, Malus*

pumila var. *niedzwetzkyana* and *Amelanchier alnifolia* (Coffin et al. 1976) and for *Acer pennsylvanicum* (Mathes 1967). Somewhat lower growth indices than those in the present work have been noted for *Malus robusta* No. 5 (Chong and Taper 1972), *Acer pennsylvanicum* and *A. pseudoplatanus* (Mathes et al. 1971). Again, the interpretation of these differences is rendered difficult by major differences between studies, such as in the growth period, basal media, etc. Two notable differences in the behaviour of subcultured callus of *F. americana* and *F. pennsylvanica* (Wolter and Skoog 1966) should be mentioned. The latter callus had much higher growth indices and secondly, that callus had an absolute requirement for pyridoxine in the culture medium as did the Wentworth calli. These differences may relate to the different origins of callus of each species, and to differing culture conditions.

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THE HABITAT OF THE OSTRICH FERN (*MATTEUCCIA STRUTHIOPTERIS*) IN NOVA SCOTIA AND PRINCE EDWARD ISLAND[1]

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Seventy-two stands of *Matteuccia struthiopteris* were located in Nova Scotia and Prince Edward Island. Associated species of trees and shrubs were recorded, and the soil was analyzed. *M. struthiopteris* is not associated with any particular plant species, but rather with specific edaphic characteristics—good drainage, a high water table, and a pH above 5.0. In areas where the soil is extremely acid (pH<4.5), this fern is restricted to alluvial habitats.

Soixante-douze peuplements de *Matteucia struthiopteris* furent réperés en Nouvelle-Ecosse et à l'Ile-du-Prince-Edouard. Les différentes espèces d'arbres et d'arbutes associées à ces peuplements furent inventoriées et le sol analysé. *M. struthiopteris* n'est associée à aucune espèce particulière de plantes; cependant, elle est associée à certains caractères édaphiques particuliers: un bon drainage, un niveau hydrostatique élevé et un pH superieur à 5.0. Dans les régions où l'acidité du sol est extrême (pH<4.5), cette fougère est restreinte aux habitats alluviaux.

Introduction

Matteuccia struthiopteris (L.) Todaro (Ostrich fern) has an almost circumboreal distribution in the northern hemisphere (Hulten 1968). In North America it occurs south to Maryland, north to every province of Canada, and north and west to Alaska (Tryon & Tryon 1982).

Along the St. John River valley, New Brunswick, young croziers or "fiddleheads" of *M. struthiopteris* have been eaten traditionally as a spring vegetable. With the introduction of the frozen product, and the subsequent expansion of the market, interest has increased in the potential for crop management and cultivation. Over the past two decades a few, very limited studies of wild stands have been conducted in Maine (Gabrielson 1964) and New Brunswick (Roberts-Pichette 1971), areas which have had an active fiddlehead industry. Subsequently, we examined the habitat of ostrich fern outside these areas of commercial exploitation, in the neighboring provinces of Nova Scotia and Prince Edward Island.

Methods

Seventy-two populations of *M. struthiopteris* were located during spring and summer of 1981, 62 in Nova Scotia, and 10 in Prince Edward Island (Appendix). Generally, five soil samples per site were taken to a depth of 10 cm. These were analyzed at the Soils and Crops Branch, Nova Scotia Department of Agriculture and Marketing. Organic matter was assessed by loss on ignition, and pH was measured from solutions of soil:water (1:1). The Bray method (0.05N NH_4Cl, 0.1N HCl) was used to measure phosphate. Potassium, calcium and magnesium were extracted with 1N ammonium acetate, the potassium being measured by atomic emission and the other two by atomic absorption. In addition, a qualitative assessment of presence and type of tree and shrub cover was done at each site.

Results and Discussion

All but four of the 72 populations of *M. struthiopteris* occurred along the margins of streams, brooks, or rivers. In these riparian sites, the fern was mainly in wooded

[1] NRCC No. 22713

intervales, but it also occurred along margins of cultivated fields, on open gravel, and in one instance in a boggy area with *Sphagnum* spp. and other characteristic wetland species. The non-riparian populations were on Cape Split and the slopes of Mount Thom. Although the plants at these sites were not obviously associated with running water, there was seepage from a high water table. These four sites also differed from the others in having a much higher percentage ($\bar{x}$=30% vs. $\bar{x}$=9.7%) of organic matter in the soil. The occurrence of *M. struthiopteris* in such habitats suggests that to classify these plants as rheophytes would be incorrect. True, Ostrich ferns withstand flooding, but they neither require flooding nor are limited solely to areas which are periodically inundated, unlike most rheophytes (van Steenis 1981). It is also worth noting that fern populations in such habitats as gravel banks, bog and wooded upland were quite large.

In Nova Scotia, the occurrence of *M. struthiopteris* is largely restricted to the northern and western parts of the province (Fig 1), where the soil is less acid (pH 4.5 to neutrality) than Gibraltar soils (pH $\leq$ 4.5) of the Atlantic Coastal Plain (Roland & Smith 1969; MacDougall & Nowland 1972). The soil types associated with the Ostrich fern were predominantly local Orthic-humo-ferric Podzols, although there were nine sites with Grey Wooded soil, and one with Orthic Regosol soil (MacDougall & Nowland 1972). Organic soils were not found at any of the sites.

Similarly, in Prince Edward Island, *M. struthiopteris* occurred on diverse, well-drained and local Orthic Podzols (Anon. 1966) with no correlation between distribution and specific soil type. The Ostrich fern is common in creek bottoms in Prince County clay regions. Farther east, in Queens and Kings counties where it is

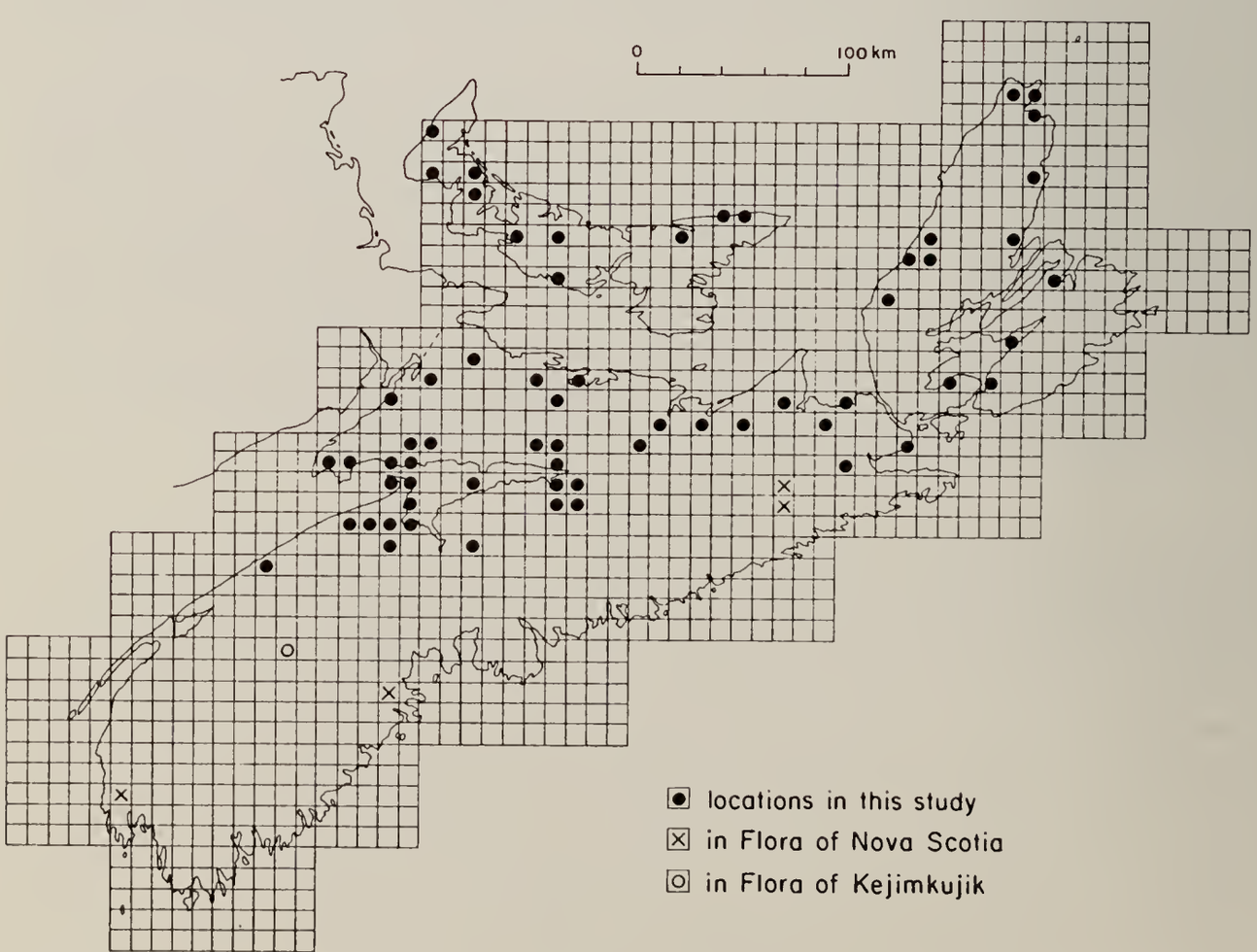

Fig 1 Locations of habitats studied (solid circles—one dot represents one or more sites found within a grid square), including some sites listed in the literature: Roland and Smith, 1969; (circles), and Roland, 1980 (crosses).

less common, it is restricted to larger streams with flood deposits (Erskine 1960).

The wide range of soil pH (4.9 - 7.5) and the usually slightly acid values of the sites ($\bar{x}$=5.8) argue against claims of a calcicole nature for this fern (e.g. Fernald 1921). Divergent pH values in stands of *M. struthiopteris* have also been recorded elsewhere, in Maine (Gabrielson 1964) and in New Brunswick (Roberts-Pichette 1971). Other edaphic properties, such as content of magnesium (109±31 ppm), calcium (1143±723 ppm), phosphorus (71±44 ppm) and potassium (156±62 ppm) varied considerably between sites.

Matteuccia struthiopteris is more common in the northern part of Nova Scotia. Wild stands of the fern were sought but not observed in Digby, Yarmouth, Shelburne, Lunenburg, Queens and Halifax counties which are covered in the main, by rather acid soils (pH≤4.5). There are records (Fig 1), however, from Kejimkujik National Park (Roland 1980), the Tusket Valley, the LaHave River near Bridgewater, and the St. Mary's River near Glenelg (Roland & Smith 1969). The first three sites are on soils of slightly higher pH than those generally found in the Atlantic Coastal Plain area, but the St. Mary's River site is a typical acid podzol. In this last case the local pH level is probably higher than the surrounding soil type would suggest, possibly because of the periodic deposition of alluvium. This was observed at the other sites of *M. struthiopteris*, along the rivers of eastern Prince Edward Island, and in several sites on siliceous soils in Nova Scotia (e.g. Barnhill River, Cumberland Co.; Jumping Brook, Victoria Co.).

In 70 of the 72 sites, *M. struthiopteris* was found with some tree or shrub cover, but did not appear to be singularly associated with any particular species or group of species (Table I). Previously, this fern had been reported associated with trees and shrubs associated with *Alnus* and *Ulmus* in Finland (Söyrinki & Saari 1980), the Federal Republic of Germany (Englert 1970; Rasbach *et al.* 1978), Maine (Gabrielson 1964), and New Brunswick (Roberts-Pichette 1970). In British Columbia, however, and the Caucasus, *M. struthiopteris* has also been found where species of *Picea* are dominant (Taylor & MacBryde 1977; Walter 1974). Porfirev (1975) reported it in association with other dominants such as broad-leaved cedar, Manchurian ash, and linden. A tabulation of the different ecotopes and vegetation found with *M. struthiopteris* led him to conclude that Ostrich fern was an indicator of mesotrophic conditions, whether found on mountain slopes, along floodplains,

Table I Tree and shrub species found with *Matteuccia struthiopteris in the 72 sites investigated*

Species	No. of Sites	Species	No. of Sites
Alnus rugosa (DuRoi) Spreng.	31	*Pyrus malus* L.	5
Ulmus americana L.	23	*Tsuga canadensis* (L.) Carr.	5
Acer saccharum Marsh.	22	*Alnus crispa* (Ait.) Pursh	4
Acer rubrum L.	17	*Amelanchier wiegandii* Nielsen	4
Prunus virginiana L.	17	*Cornus stolonifera* Michx.	4
Acer spicatum Lam.	16	*Quercus borealis* Michx.	4
Betula alleghaniensis Britt.	15	*Betula populifolia* Marsh.	3
Salix L. spp.	14	*Picea rubens* Sarg.	3
Abies balsamea (L.) Mill.	11	*Sambucus* L. spp.	3
Fraxinus americana L.	10	*Ostrya virginiana* (Mill.) K.Koch	2
Picea glauca (Moench) Voss	7	*Picea mariana* (Mill.) BSP	2
Betula papyrifera Marsh.	5	*Pinus strobus* L.	1
Crataegus L. spp.	5	*Populus grandidentata* Michx.	1
Populus balsamifera L.	5	*Populus tremuloides* Michx.	1

or, occasionally, in swamps. Our results support a similar conclusion. There seems to be little direct correlation between occurrence of Ostrich ferns and tree/shrub vegetation. *M. struthiopteris* appears to be associated with well-drained soils, high water table, and moderate pH.

The potential for commercial exploitation of stands of Ostrich fern in Nova Scotia and Prince Edward Island is very limited, as the populations at most of the sites were generally too small to be exploited profitably on a continual basis. There are, of course, some larger stands throughout both provinces, but it is our opinion that a fiddlehead industry could not be supported from present wild resources.

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Appendix

Study sites in Nova Scotia and
Prince Edward Island

NOVA SCOTIA: *Annapolis:* Oak Hollow Brook, *Kings:* Cornwallis River, Elderkin Brook, Ryan Brook, Near Cape Split, Hiking trail to Cape Split, Trail to Cape Split, Mill Creek, White Water, Rockland Brook, Berwick, Greenwich, Deep Hollow Road, Gaspereau River, *Hants*: South Maitland, Rennie's Brook, Meander River, *Colchester*: Beaver Brook, Stewiacke River, Chiganois River, Great Village River, Green Creek, Debert River, Folly River, Mattatall Brook, Annandale, Brookfield, *Cumberland*: West Moose River, Parrsboro, Jeffers Brook, West Diligent River, Fowler Brook, McRitchie Brook, Barnhill River, St. George's River, Shinimecas River, Wallace River, *Pictou*: Mt. Thom, Union Center, Pinetree, Marshy Hope, *Antigonish*: Brierly Brook, Pomquet River, Tracadie River, *Guysborough*: Meadow Brook, Ogden, *Richmond*: Dundee, The Points West Bay, Soldier's Cove, *Cape Breton*: Big Pond, Scotch Lake, *Victoria*: North River Bridge, Ingonish River, Middle Aspy River, Wilkie Brook, Jumping Brook, *Inverness*: Lake O'Law, Margaree Forks, Gillisdale, Big Cove River, Glendyer Station, Fordview. **PRINCE EDWARD ISLAND:** *Prince*: Northam, Enmore River, Mount Royal, Roseville, Dunk River, *Queens*: New Glasgow, DeSable River, *Kings*: Morell River, Naufrage River, Glencorradale.

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CANADA GOOSE HUNTER PROFILE, SUCCESS AND EXPENSES ON PRINCE EDWARD ISLAND

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Canada goose hunter profile, technique, effort, harvest and cost were documented during fall migration on a 20,000 ha area of Prince Edward Island in 1974 and 1975. In 1974, 3.7 geese per hunter were shot, but in 1975 extensive fall ploughing resulted in geese feeding more frequently on tidal flats and the average kill dropped to 1.9 birds. Hunters using blinds and decoys bagged more birds than those stalking geese in 1974, but not in 1975. In both years harvest was unrelated to numbers of geese present on the area. In 1974, harvest was related directly to hunting efforts, but not in 1975. The average cost for a season of hunting was about $70 per individual.

En 1974 et 1975, différentes aspects de la chasse à l'Oie du Canada furent étudies, pendant la migration d'automne, dans une région de 20,000 hectares située dans l'Ile-du-Prince-Edouard. Le profile du chasseur, sa technique, l'effort de chasse, la récolte et le coût de cette chasse furent documentés. En 1974, chaque chasseur a abattu 3.7 oies. En 1975, ce chiffre est tombé à se nourrir plus frequemment dans les plaines intertidales. En 1974, et non en 1975, les chasseurs qui ont utilisé des caches et des oiseau de leurre on récolté plus de gibiers que ceux qui ont chassé a l'affût. Pendant ces deux années, la récolte ne fut pas reliée au nombre d'oies présentes, dans la région étudiée. En 1974, et non en 1975, la récolte fut directement reliée à l'effort de chasse. Le coût moyen d'une saison de chasse s'est éléve a environ $70 par individu.

Introduction

Prince Edward Island provides excellent habitat for migrating Canada geese (*Branta canadensis canadensis*). Shallow bays and tidal flats bordered by agricultural areas attract large numbers of geese during spring and autumn (Martin and Guignion 1983). Recently, the number of Canada geese both in the Atlantic Flyway and staging on Prince Edward Island has been increasing (Bellrose 1976, Atlantic Migratory Bird Technical Committee 1976). The location of large cultivated areas close to water, the predominance of resident hunters, and informal arrangements for hunting on fields have maintained a pattern of high quality, but low cost hunting on Prince Edward Island. The current trend towards large scale monocultures operated by a few individuals may change this tradition. Grain stubble fields are becoming increasingly more difficult to obtain and many gunners fear the days of inexpensive hunting are numbered. Our study documents goose hunter profile, techniques, harvest, effort expended, and costs incurred on a 20,000 ha area of Prince Edward Island during 1974 and 1975.

Study Area

The study area, located on the southern coast of Prince Edward Island, includes portions of the Dunk and Wilmot Rivers and Salutation Cove, plus surrounding fields which are cultivated extensively. Martin & Guignion (1983) describe the area in more detail.

Methods

A survey of goose hunting activities on the study area was conducted during the autumn of 1974 and 1975. Shortly before hunting season, advertisements were placed in local newspapers and on radio stations to inform all hunters and landowners of the study. Twice weekly, on Saturday and 1 day through the week, we flew over the area in a grid pattern with a Cessna 172 aircraft during early morning to count geese, and to locate blinds and sets of decoys. From field observations and interviews with landowners and hunters, data on residency, types and locations of blinds, equipment used, how fields were acquired, and hunting effort, success and costs were obtained.

Goose hunters were interviewed initially by a personal visit and later by phone. Subsequent contacts were made in proportion to frequency of their hunting excursions. Record sheets were provided and information was obtained sometimes by talking to the hunter's partners, the landowner, or other people. Data were cross-checked when exaggerations were suspected and figures were adjusted accordingly.

Costs of hunting were determined for the 1975 season by calculating expenditures for travel, guns, ammunition, decoys, goose calls, and licences. To obtain travel expenses round trip mileages from residence to blind were calculated for each excursion. Each hunter was accorded 1 trip for setting up blinds and 1 additional trip was added for every 10 excursions because those who hunted frequently generally used several fields and periodically established new blind sites. When hunters travelled together, the driver was assigned the costs of transport. Attempts were not made to compute distances covered by those who followed daily flight patterns of geese. Hence, only travel while on hunting excursions was considered and season totals of less than 20 km were not included. Because all of the hunters, except the 4 non-residents, lived within a daily commuting distance, no costs were computed for meals or lodging. Transportation costs were calculated at the rate of 10.6 cents per km (Provincial government kilometerage rate in 1975). To obtain the annual cost of a goose gun, the mean age of firearms owned by all hunters was calculated and divided by individual purchase prices. Average cost of shells, and goose calls (considered to be replaced every 5 years) were obtained from local stores. It was assumed that decoys would last for 20 years and were depreciated at 5% per year of their original price.

Results and Discussion

All known active goose hunters were contacted. Those who used blinds and decoys were easy to locate and for them we obtained complete information on harvest and total time spent hunting. It was impossible to obtain complete data for other aspects of the study and thus sample size varies with the specific topic discussed. Only 1 hunter refused to give any information.

Goose Hunter Profile

Information was obtained on 218 individuals who used the study area for all or part of their goose hunting activities during 1974 and 1975. About 60% of these hunted in the area both years. Two hundred were classified as *bona fide* hunters because they used decoys and set up blinds, and 18 were considered *casual* because they stalked geese in fields or shot them while pursuing ducks.

The majority of hunters (87.2%) lived on the study area or in small towns within 20 km. The 4 non-residents (1.8%) that hunted on the study area were former residents or had relatives in the Province. In 20 (58.9%) of 34 hunting parties at

least 1 member was a landowner or his immediate family owned the field. By sharing with the owner geese shot or by performing favors (e.g., fixing farmer's machinery promptly during harvest), 5 (14.7%) additional parties obtained hunting rights. Another 5 required no permission, as they used public land or had floating river blinds. Three (8.8%) parties hunted on their neighbour's property, and only 1 (2.9%) leased hunting rights to a 40 ha grain field.

Blinds were constructed so that they were easy to set up and did not create potential friction with farmers. Of those observed, 85 (62.0%) were situated along fence lines or hedgerows, 43 (31.4%) were in stubble grain fields, and 9 (6.6%) were along stream courses in fields or floating on a river. Of those located in stubble fields, 36 were pits and 7 were box-like structures on top of the ground.

In general, 1 or 2 hunters went out consistently and were joined occasionally by other partners. The number of *bona fide* hunters on each excursion varied from 1 to 5 ($\bar{x}$ = 2.7), but as many as 8 different men reported using the same blind periodically during the season. *Casual* hunters often went out alone, or occasionally with 1 or 2 others. Many integrated their excursions with work, and went shooting in the early morning or evening. Some landowners hunted only after a flock was observed feeding in their fields for several days. A few hunters were retired or took holidays during the season and spent 6 to 10 hours per day in their blinds. Frequency and timing of excursions were determined generally by weather, work commitments, public holidays and feeding patterns of geese. Goose hunters tended to be specialized as 29.1% hunted only geese and an additional 63.4% restricted their sport to waterfowl species.

Landowners traditionally reserved stubble fields for friends or relatives even though they might be used only once or twice.

Currently hunting pressure is light on the study area, but because of new directions in agriculture, this likely will change. As small farms are incorporated into larger units (Martin and Guignion 1983), there will be a reduction in hunting opportunities since normally only friends or employees of the landowner are allowed access. This creates resentment among sportsmen who view large infrequently used fields as akin to private hunting reserves. Elsewhere on Prince Edward Island, a system of buying hunting rights to agricultural land has begun. Hunters on the study area were opposed to the practice of leasing goose fields. They felt their opportunities to obtain sites were threatened because they would be unable to compete financially with wealthy hunters, especially non-residents, and thus would be denied access to their traditional area.

Hunting Effort and Harvest

A 3-way contingency analysis examining year, hunting technique and likelihood of success of goose hunting parties (Table I) showed only a year effect (x^2 = 6.90, 1

Table I Success of **bona fide** and **casual** goose hunting parties on study area, 1974-1975

Year	Type of Hunting Party	Total Parties n	Successful Parties n(%)	Total Geese Shot n	Average Number of Geese Shot per Party
1974	**Bona Fide**[1]	46	36(78.3)	597	13.0
	Casual [2]	12	7(58.3)	32	2.7
	All Parties	58	43(74.1)	629	10.8
1975	**Bona fide**	53	27(50.9)	311	5.9
	Casual	9	5(55.6)	10	1.1
	All Parties	62	32(51.6)	321	5.2

[1] used blinds and decoys

[2] did not use blinds and decoys

Table II Individual goose hunter success on study area, 1974-1975

Year	Type of Hunter	Number of Hunters	Successful Hunters n (%)	Geese Harvested n	Average Number of Geese Harvested per Hunter	Average Number of Geese Harvested per Successful Hunter
1974	**Bona fide**[1]	151	98(64.9)	597	4.0	6.1
	Casual [2]	20	10(50.0)	32	1.6	3.2
	All Hunters	171	108(63.2)	629	3.7	5.8
1975	**Bona fide**	152	65(42.8)	311	2.0	4.8
	Casual	15	6(40.0)	10	0.7	1.7
	All Hunters	167	71(42.5)	321	1.9	4.5

[1] used blinds and decoys

[2] did not use blinds and decoys

Table III Bona fide goose hunter efforts and success on study area, 1974-1975

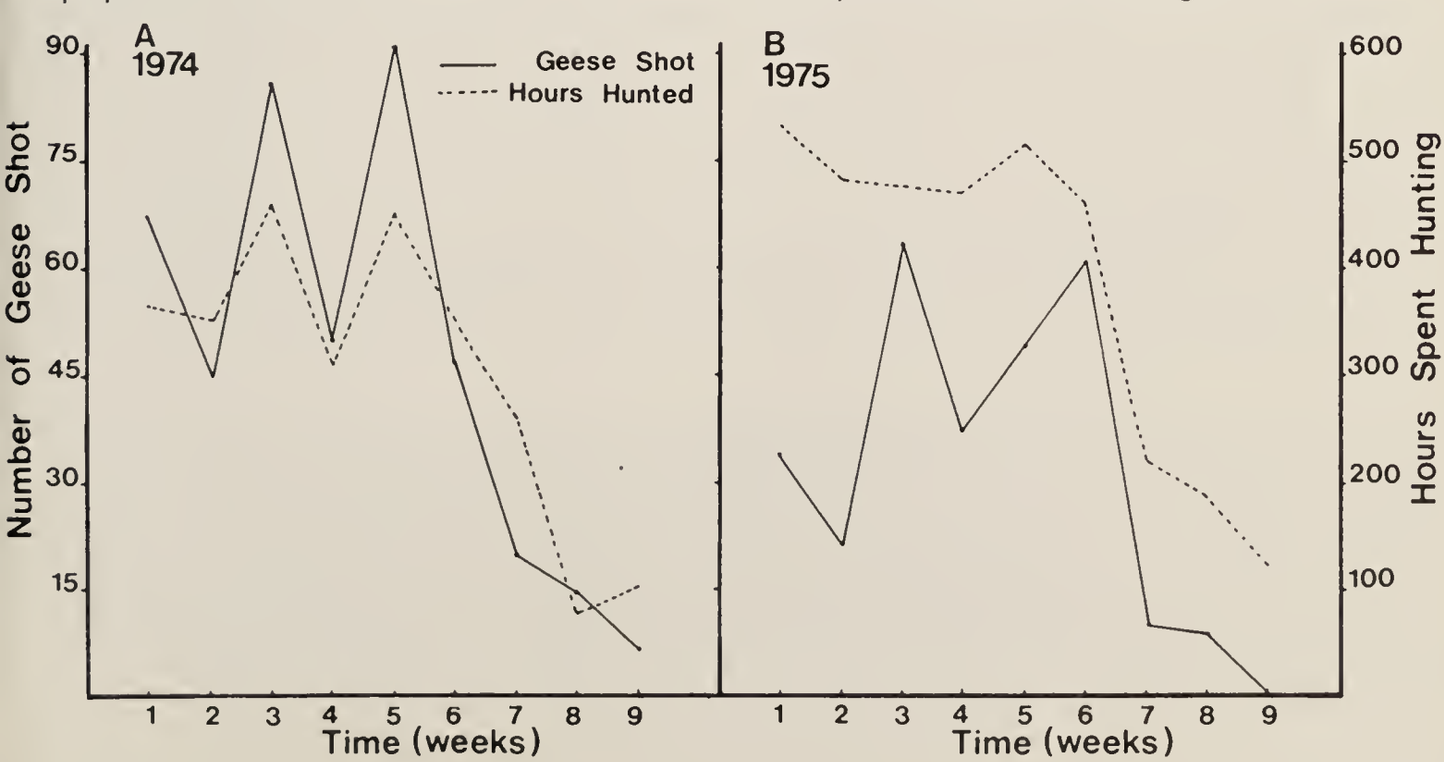
Year	Hunter Category	Number of Hunters	Total Days Hunted	Average Number of Days Hunted	Total Hours Hunted	Average Number of Hours Hunted	Average Number of Geese Shot per Hour
1974	Successful	98	759	7.7	3328	34.0	0.18
	Unsuccessful	53	144	2.7	624	11.8	0.00
	All hunters	151	903	6.0	3952	26.2	0.15
1975	Successful	65	462	7.1	2142	33.0	0.15
	Unsuccessful	87	403	4.6	1718	19.7	0.00
	All hunters	152	865	5.7	3860	25.4	0.08

df, $p < 0.01$). This between-year difference was due mainly to a change in the proportion of *bona fide* groups that were successful (Yates corrected $x^2 = 6.63$, 1 df, $p < 0.05$). Parties using blinds and decoys shot more geese than *casual* ones in both years, but there were more hunters in *bona fide* parties. Similar trends were found in geese harvested by individual hunters (Table II). A significant interaction between years and likelihood of success of individuals was found (3-way contingency analysis, $x^2 = 14.95$, 1 df, $p < 0.001$), and this again was due to a decline in the proportion of successful *bona fide* hunters from 1974 to 1975 (Yates corrected $x^2 = 13.96$, 1 df, $p < 0.001$). In terms of absolute success, the average kill per hunter declined from 1974 to 1975 on the study area ($t = 2.98$, 336 df, $p < 0.001$). *Bona fide* hunters shot more geese than *casuals* in 1974 ($t = 4.23$, 169 df, $p < 0.001$), but not in 1975 ($t = 1.23$, 165 df, $p > 0.05$). In 1975, unusually warm, dry weather permitted farmers to do extensive fall cultivation and geese consequently spent most of their time feeding on tidal flats (Martin and Guignion 1983). Hence the use of blinds and decoys increased the harvest only when geese were feeding in fields as they did in 1974, and not when they spent considerable time on coastal marshes and tidal flats.

It was impossible to compute the numbers of hours spent hunting by *casual* hunters because often they were engaged in other activities while pursuing geese. The total number of hours logged by all *bona fide* hunters was approximately the same each year (Table III), but the average harvest per effort declined from 1974 to 1975 ($F = 5.09$, 1 df, $p < 0.05$). A 2-way anova of geese shot per hour showed that successful individuals spent more time in their blinds ($F = 37.64$, 1 df, $p < 0.001$) than unsuccessful gunners and this did not vary between years ($F = 1.37$, 1 df, $p > 0.05$).

Certain hunters were unsuccessful but very persistent. One hunter spent 98 hours to bag 1 goose, while another spent 180 fruitless hours in a blind. On the other hand, some hunters were very successful and 1 in 1974 managed to bag 46 geese in 96 hours.

Harvest versus effort was computed weekly throughout the season (Fig 1). Data for individual hunters were used only when we could determine total harvest and time spent hunting for each week. In 1974, peak harvest occurred during weeks 3 and 5 of the season (Fig 1A). Harvest during week 3 corresponded with peak numbers of geese (2040) observed on the study area, but during week 5, the staging population had declined to less than 40% of the peak (Martin and Guignion 1983).



During 1974, harvest was related directly to time spent hunting (Fig 1A). In 1975, peak harvest occurred during weeks 3 and 6 of the season (Fig 1B), before maximum numbers of geese were observed (Martin and Guignion 1983). Hunting effort in 1975 was relatively constant during the first 6 weeks of the season and was unrelated to harvest. During week 7, when the greatest number of geese (2420) was observed on the area (Martin and Guignion 1983), only 9 geese were reported shot. Although the number of birds present on the area was slightly higher in 1975 (Martin and Guignion 1983) and hunting effort was comparable both years, total harvest was lower in 1974, and this appeared to be due primarily to changes in foraging patterns of geese which were dictated by weather and agricultural practices.

Annual goose harvest on Prince Edward Island during 1971-75 ranged from 6400 to 11300 geese (Cooch et al. 1974, Cooch and Newell 1977). The Prince Edward Island Fish and Wildlife Division indicated from their surveys that geese shot per active waterfowl hunter ranged from 2.8 to 3.0 during 1971-74 and decreased to 2.4 in 1975 (R. Dibblee, pers. comm.). The Canadian Wildlife Service reported on the basis of wing surveys a harvest on Prince Edward Island of 5.3 geese per successful hunter in 1974 and 4.2 in 1975 (Cooch 1976).

These figures are similar to our values of 5.8 geese per successful hunter in 1974 and 4.5 in 1975 (Table II). During 1971-75 total harvest on Prince Edward Island equalled or exceeded that of other Atlantic Provinces, and the average number of geese shot per licensed waterfowl hunter was either equivalent to or above that experienced on the prairie provinces (Cooch 1976, Cooch et al. 1974).

Hunting Expenses

The major cost incurred by *bona fide* hunters was the purchase of a "goose gun". Some hunters had inexpensive models but most owned automatic guns chambered for "three inch" magnum shells and a few used very expensive models. The majority of hunters preferred 12 gauge shotguns, but a few used 10 gauge. Average annual cost of a gun was about 45% of total expenses (Table IV).

Table IV Bona fide goose hunter expenditures, 1975

Type of Expenditure	Average cost per Hunter per season
Guns	$31.23
Ammunition	10.34
Decoys and Calls	7.85
License[1]	4.76
Transportation	15.87
Total	$70.05

[1] Data were used from 123 hunters but 26 of these were farmers and did not require a provincial hunting license.

Transportation was the second major expense involved in goose hunting on the area (Table IV), but when compared to other areas of Canada, it was low because of the short distances most hunters had to travel. A survey done in British Columbia in 1972 for all types of resident hunters revealed transportation to be the major expense accounting for $142 of a total cost of $290 per hunter, and an average of $39 was spent on food, alcohol and lodging (Pearse Bowden Economic Consultants Ltd. 1972).

Ammunition accounted for 14.8% of the hunting costs. Slightly fewer than 50 shells (2 boxes) were used per person per season, although the amount varied greatly. Commercial decoys made of plastic, rubber or styrofoam were most popular, but some hunters had handmade wooden decoys or silhouettes. Usually there were 2 or 3 goose calls per party; a few gunners called geese by voice. All hunters had to obtain a Federal migratory bird permit but only those who were not *bona fide* farmers required a Provincial hunting permit. The cost of licenses was thus a minor expense. Only 1 hunter claimed to have leased rights to a stubble field and he did not reveal the price involved.

Goose hunters in the study area spent an average of $70 in 1975 on their sport (Table IV). The overall cost would have been similar in 1974 because an approximately equal effort was expended by hunters in both years. The average Canadian waterfowl hunter spent $79.03 for the 1961 season (Benson 1963) and during 1971, total expenditures were estimated at $107.41 per migratory bird hunter (Benson and Willey n.d.). Thus goose shooting on Prince Edward Island remains a relatively inexpensive sport, primarily because of the short travelling distances involved and the traditional informal arrangements required for access to hunting areas.

Prince Edward Island is an important stopover area on the Atlantic Flyway (Martin and Guignion 1983) and high quality goose hunting exists on agricultural lands. Non-resident migratory bird hunting permits issued for Prince Edward Island have increased during 1967 to 1976 from 39 to 277 (A. Godfrey, pers. comm.), while resident permits issued have increased from 3047 to 5718 (Benson 1968, Cooch et al. 1978). Most non-resident permits during the above period were issued for goose hunting. Although non-resident hunting has increased over the last decade, it does not yet account for a significant proportion of the migratory bird hunting on Prince Edward Island. With increasing numbers of Canada geese utilizing large agricultural fields, it can be anticipated that hunting pressure and costs will greatly accelerate in future years.

ACKNOWLEDGEMENTS

This study was one aspect of a 2-year waterfowl project undertaken as part of an interdisciplinary research project on the Dunk River conducted by the University of Prince Edward Island and government agencies. Funding was provided by the Senate Research Committee of the University and the National Research Council of Canada. We acknowledge field assistance from E. Hickey and D. Martin. The Prince Edward Island Fish and Wildlife Division provided advice and background information, and E. Morello prepared the figure. We thank hunters and landowners for their cooperation. D. Ankney, R. Curley, R. Dibblee, A.R. Lock, and D. MacAskill contributed comments on the manuscript. C.S. Findlay assisted with the statistical analysis.

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Volume 32 (3/4), pp. 145-146

CASTILLEJA COCCINEA (L.) SPRENG. (SCROPHULARIACEAE), A FIRST RECORD FOR NOVA SCOTIA*

The occurrence in Nova Scotia of Indian paintbrush or scarlet painted-cup, *Castilleja coccinea* (L.) Spreng., is reported for the first time. Hitherto, the Bruce Peninsula in Ontario was the reported eastern limit of distribution of this species in Canada, and southern Maine the eastern limit in North America (Peterson & McKenny 1968; Scoggan 1979). We have been unable to locate any casual reports or collections of *C. coccinea* in Nova Scotian herbaria prior to this record.

Castilleja coccinea (Figs 1, 2) was first sighted in late June, 1982, along route 103 at Chester Basin, Lunenburg County (44° 34'N, 64° 19'W), and identification was confirmed with Scoggan's (1979) keys. About 300 flowering stems were observed, mostly concentrated within a 20-m stretch of roadside, with outlying stray individuals bringing the total extent of the colony to about 40 m. The species grew in damp gravel bordering the shallow ditch, and also in drier, stony soil at slightly higher levels along the roadbank. Plants were up to 60 cm tall and appeared healthy; a few were branched, though most were simple. Common associates were the herbaceous species *Achillea millefolium* L., *Anaphalis margaritacea* (L.) Clarke, *Fragaria virginiana* Dcne., *Hieracium caespitosum* Dumort., H. *pilosella* L., and *Trifolium hybridum* L.; the shrubs *Comptonia peregrina* (L.) Coult. and *Salix* sp.; and young trees *Betula papyrifera* Marsh., *Picea glauca* (Moensch) Voss and *Populus tremuloides* Michx.

In 1983, the colony was about the same size as in 1982, with a probable slight increase in the number of plants. In late July, after the peak period of flowering, a number of smaller, later-blooming stems were noted. Clipping of roadside shrubs and trees by Department of Transportation maintenance staff had caused minor disturbance and some of the *C. coccinea* had been trampled in the process.

The occurrence of *C. coccinea* in Nova Scotia represents a radical eastward extension of the range of this species, and results in a widely disjunct distribution. As there is little human habitation in the immediate vicinity of the stand, and as we are unaware of attempts to cultivate *C. coccinea* as an imported wildflower in gardens of nearby Chester Basin, it is unlikely that these plants are garden escapes. The most probable origin is as a contaminant in the grass-clover seed mixtures used by the provincial Department of Transportation to consolidate roadbanks, as much of this seed is obtained from Ontario and other Canadian provinces within the range of *C. coccinea* (Nova Scotia Department of Transportation, in verb.).

Whatever the means of introduction, the question remains whether this species will become permanently established in this province. The number of individuals suggests that *C. coccinea* has been present at this site for at least several years, having multiplied from one or a few chance arrivals. The relatively acid soils, however, of this part of Nova Scotia (pH $\leqslant$ 5.0; Soils of Nova Scotia 1972) may preclude its long-term survival and spread in this area (S. van der Kloet, in verb.). On the other hand, the associated vegetation includes a number of genera and species known to host this semiparasitic plant (Malcolm 1966). Additionally, as semiparasitic Scrophulariaceae prefer open, sunny habitat (Musselman & Mann 1977), the roadside colony at Chester Basin may benefit from the practice of pruning shrub and tree species before they overshadow the area.

Voucher specimens have been deposited in the herbaria of Acadia University, Wolfville, (ACAD), the Nova Scotia Museum, Halifax (NSPM), and the Nova Scotia Agricultural College, Truro (NSAC).

*N.R.C.C. No. 22714

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Fig 2 Close-up of a flowering stem from the colony in Fig 1.
Fig 1 Part of the stand of *Castilleja coccinea* near Chester Basin.

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PROCEEDINGS OF MEETINGS 1982-83

HALIFAX CHAPTER

1st Ordinary Meeting, 13 Oct. 1982
"Canadarm, the Canadian Technological Success". Karl Doetsch.

2nd Ordinary Meeting, 1 Nov. 1982
"Microbial Processes at Deep-Sea Hydrothermal Vents". Holger Jannasch, Woods Hole, Mass.

3rd Ordinary Meeting, 6 Dec. 1982
"The Modelling of Acoustic Propagation in Coastal Waters". David F. Chapman, Defence Research Establishment Atlantic.

4th Ordinary Meeting, 10 Jan. 1983
"The Edible Fern, A History of the Fiddlehead". P. Von Aderkas, Atlantic Regional Laboratories, National Research Council, Halifax.

5th Ordinary Meeting, 7 Feb. 1983
"Fish Passage Through Hydroelectric Turbines". Paul Ruggles, Montreal Engineering.

1st Extraordinary Meeting, 14 Feb. 1983
"The Disposal of Hazardous Wastes". Ian C. Travers, Environmental Protection Service.

6th Ordinary Meeting, 7 Mar. 1983
"Water, Molten Rocks and Other Remarkable Liquids". Walter Kauzmann, Visitor, Atlantic Regional Laboratories, Halifax.

Annual General Meeting, 25 April 1983
"The Regional Nuclear Magnetic Resonance Centre". W. Jones, Dalhousie University.

VALLEY CHAPTER

1st Ordinary Meeting, 8 Nov. 1982
"Mushrooms of Nova Scotia". Ken Harrison, Acadia University.

2nd Ordinary Meeting, 17 Jan. 1983
"Oil of Evening Primrose". M.F. Nanku. Efamol Research Institute.

3rd Ordinary Meeting, 21 Feb. 1983
"Botulism—New Technology, New Concerns". Eric Jackson, Agriculture Canada, Kentville.

4th Ordinary Meeting, 14 Mar. 1983
"Mountain Building in Western Canada". Robert Raeside, Acadia University.

5th Ordinary Meeting, 18 Apr. 1983
"Wine making, a viable industry for Nova Scotia". Rodger Dial, Grand Pré Wines.

THE PRESIDENT'S REPORT

The Institute, like many other organizations, is feeling the effects of the downturn in the economy. In many respects this was a momentous year marked by the publication of Dr. A.E. Roland's book *Geological Background and Physiography of Nova Scotia* and its attendant monetary problems. This book is now available to members at a special price through the Museum. It was a long, hard struggle for those involved and many thanks must go to those who assisted in getting the publication completed and the book available to the public. The Atlantic Geoscience Society also publicized the book in their newsletter.

The program of meetings during the year consisted of six ordinary meetings, one joint meeting, joint sponsorship of the A.C. Neish Memorial Lecture, and two special lectures at Dalhousie. The venue for the regular meetings was the Museum, but two meetings were held at the Nova Scotia Archives. Thanks to both organizations for the use of these facilities. Two special lectures held in September were by Dr. Jack Vallentyne (on Ecosystems), the joint lecture with the Atlantic Geoscience Society was by Dr. Robert J. Wetmiller (on the 1982 Miramichi earthquake). The A.C. Neish Memorial lecture was by Dr. Karl Doetsch (on the CANADARM). The lectures and presentations at the ordinary meetings covered the usual wide range of subjects. In recent years the Institute has made special efforts to ensure that there is coverage of both the natural and physical sciences on both the applied and pure aspects. In this regard, joint sponsorship of lectures is very helpful. It also brings us more publicity than our ordinary series of lectures, and brings the activities of the Institute to the attention of a larger range of potential members.

A recommendation to the incoming Council is to place more emphasis on public relations. Although the local radio, TV, and newspapers publicize our activities as part of their public service announcements, it is probably insufficient to ensure good turnouts at each meeting. A more personal relationship with the media should result in improved attendance. One member of Council could possibly be assigned this task.

The major problem facing the Institute at the beginning of the year was the cost overrun on publishing Roland's book. This turned out to be an extremely large undertaking in relation to the resources available to the Institute. Furthermore, we did not have the experience to understand business problems related to publishing a book of this nature. As a result, it looked like the 120th President also would be the Institute's last. However, an extremely sympathetic hearing from the Museum authorities (particularly Dr. J. L. Martin) brought assistance from their publication fund to overcome this deficit and keep us in a sound financial position. One of the lessons to be learned from this activity is that the Institute consists of people who can donate only a limited amount of time to the Institute; they are not in a position to retain control of a large project such as Roland's book. Therefore, I recommend that in the future activities in this area remain at the level similar to those of the Proceedings; thus, if something goes wrong, the liability is limited too.

Because of the high cost of single mailings, notices of meetings were reduced to two: a fall and a spring program mailing. Publicity for each meeting, however, was circulated prior to each meeting. On a motion by Dr. John van de Meer, our former Editor (Dr. Jack McLachlan) was made a life member to honour his many years of work as an Institute Editor. During his time as Editor, the Proceedings gained steadily in stature; this process, we know, will continue with the current Editor, Dr. Hicks.

The only working Chapter the Institute has is in the Annapolis Valley. However, without a formal means of reporting, communications between the Institute in Halifax and the Valley Chapter are tenuous at best. The next Council should delegate a member to ensure that a communication pipeline is established and kept open.

Since I live and work on the Dartmouth side of the Harbour, there have been numerous times when I have had to fall back on the other members of Council for assistance. I would like to thank all members for their support and, in particular, Dr. Alan Taylor, a steadfast worker on behalf of the Institute, who assisted me greatly in the latter half of the year; and, our outgoing Treasurer, Dr. John van de Meer, who freely gave of his time to solve the Institute's financial problems; also, the officers of the Institute—for, without them, the ongoing activities of the Institute would be difficult . . . if not impossible.

Finally, I would like to wish the incoming President, Dr. Alan MacLean, a very successful and pleasant year. I know he will be supported by a strong group.

John R. Helliwell

2647 084 PS

INSTRUCTIONS TO AUTHORS

The *Proceedings of the Nova Scotian Institute of Science* publishes the proceedings of the Institute and original articles, including notes, pertaining to the natural sciences of the Atlantic Provinces, especially in biology and geology. Manuscripts may be either in English or French, and acceptance for publication is based on recommendations of referees.

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Spelling should follow that of **Webster's Third New International Dictionary**, and authors are responsible for consistency in spelling.

Abbreviations, nomenclature, and symbols for units of measurements should follow international recommendations. Metric units, SI units and decimals should be used whenever possible. Use day/month/year sequence for dates. Do not use periods after such abbreviations as "mm, kg, DOE, NRC, etc."

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